THE
POPULAR SCIENCE
MONTHLY.

AUGUST, 1903.

MODERN VIEWS ON MATTER.*

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THE nature of matter has been regarded by philosophers from many points of view, but it is not from any philosophic standpoint that I presume in this university to ask you to consider the subject under my guidance. It is because new views as to the structure and properties of what used to be called the ultimate atom are now being born, and because these views, whether they succeed in ultimately establishing themselves in every detail or not, are of surpassing interest, that I have chosen this very recently deciphered chapter of science as the subject-matter for the lecture—the Romanes lecture—to be given this year in remembrance of a man whom I knew as a friend, and whose mind, if he had been alive to-day, would have been widely open to these most modern developments of physical science. Nor would the admittedly speculative character of some of the hypotheses now being thrown out have deterred him from hearing about them with the keenest interest.

If I may venture to say so, it is the more philosophical side of physics which has always seemed to me most suitable for study in this university; and although I disclaim any competence for philosophic treatment in the technical sense, yet I doubt not that the new views, in so far as they turn out to be true views, will have a bearing on the theory of matter in all future writings on philosophy; besides exercising a profound effect on the pure sciences of physics and chemistry, and perhaps having some influence on certain aspects of biology also.

* The Romanes Lecture, delivered in the Sheldonian Theatre, Oxford, June 12, 1903. Copyright by The Science Press.

In admitting that I am going to promulgate a speculative hypothesis, that is a hypothesis for which there is evidence but not yet conclusive evidence, I must not lead you to suppose that the whole of what I have to say is of this character. On the contrary, much of it is certain, that is to say, is accepted by a consensus of opinion to-day among those who by reason of study are competent to judge. I will endeavor carefully to discriminate between what is in this sense certain and what must still be regarded as doubtful and needing further support.

To treat the subject properly, to give all the evidence as well as the results, would need a volume, or a course of lectures; and in order to be brief I must frequently be dogmatic, but I shall only intend to be so in those places where I feel sure that the physicists present (whom here I salute) will agree with me. When I have a dogma of this kind to propound I shall call it a thesis. The more speculative opinions I shall plainly denominate hypotheses.

1. My first thesis is that an electric charge possesses the most fundamental and characteristic property of matter, viz., mass or inertia; so that if any one were to speak of a milligram or an ounce or a ton of electricity, though he would certainly be speaking inconveniently, he might not necessarily be speaking erroneously. At the same time it would be well to mistrust any one who employed such a phrase, except in speaking to experts: he would most likely be talking nonsense; but if he talks nonsense to experts, his blood is on his own head.

In order to have any appreciable mass, however, an electric charge must either be extremely great or must be extremely concentrated; and, unless it is to be utterly masked by the matter with which it is associated, it must be the latter: that is to say, it must exist on bodies of far less than ultra-microscopic size. The mass or inertia of a charge depends upon two factors—the quantity of electricity in it, and its potential—and by concentrating a given charge on to a sufficiently small sphere, the latter factor can be raised theoretically to any value we please, and thus any required inertia can be obtained; unless a stage is reached at which it becomes physically impossible to concentrate it any more.

2. The next thesis is a very simple and familiar one, and dates virtually from the time of Faraday, though the conception has gradually gained in clearness and solidity: it is that every atom of matter can have associated with it a certain definite quantity of electricity called the ionic charge, that some atoms can have double this quantity, some treble, and so on, but that no atom or any piece of matter can have a fraction of this quantity, which therefore appears to be an ultimate unit, a sort of 'atom,' of electricity. The ratio of the charge to the weight of a material atom is measured with accuracy in electrolysis,

in accordance with what are called Faraday's laws; and in so far as the mass of the atom itself is otherwise approximately known, the quantity of electricity which can be associated with it is known with a similar degree of approximate accuracy.

3. Now mathematical data were given by J. J. Thomson in 1881 which enable us to say that if the charge of electricity usually associated with a single monad atom of matter were concentrated on to a spherical nucleus one-hundred-thousandth of an atom's dimension in diameter, it would thereby possess a mass about one-thousandth of that of the lightest atom known, viz., the hydrogen atom.

Such a hypothetical concentrated unit of electricity it has become customary to call an 'electron,' a name invented by Dr. Johnstone Stoney to designate the so to speak 'atom' or smallest known unit of electric charge. Every electric charge is to be thought of as due to the possession of a number of electrons, but a fraction of an electron is at present considered impossible, meaning that no indication of any further subdivision has ever loomed even indistinctly above the horizon of practical or theoretical possibility.

The electrification of an atom of matter consists in attaching such an electron to it, or in detaching one from it. An atom of matter possessing an electron in excess is called an 'ion'; and there is reason to know that, considered as a charged body, its charge is that which we have been historically accustomed to designate 'negative'; whereas an atom of matter with one electron in defect is that which has historically been called a 'positive' ion.

This inversion in the natural use of the names positive and negative is inconvenient but accidental and not really serious; it dates from the time of Benjamin Franklin.

These ions or traveling particles of matter have been long known. A liquid or a gas conducts because of the locomotion of its charged particles. The particles travel in an electric field because of their attached charges, all the positive going one way, and all the negative the other way; and each kind of matter possesses an intrinsic or characteristic ionic velocity, when urged by a given field through a given solution. The charges may be likened to horses or other propelling agency, and the atom to the vehicle or heavy body which is dragged along. The speed of travel through liquids is very slow, but through gases is considerably quicker, partly because there is less resistance, and partly because it is easier to maintain a steep gradient of potential in a medium where the ions are not too numerous.

The act of production of such ions is styled 'ionization,' and the process has been employed to explain very many facts in both physics and chemistry.

As an example, Röntgen rays passing through air ionize it and so render it conducting for a time: wherefore they are able readily to discharge electrified bodies, in this secondary way.

It may be convenient here to emphasize the dimensions of an electron as above specified, for the arguments in favor of that size are very strong, though not absolutely conclusive; we are sure that their mass is of the order one thousandth of the atomic mass of hydrogen, and we are sure that if they are purely and solely electrical their size must be one hundred-thousandth of the linear dimensions of an atom; a size with which their penetrating power and other behavior is quite consistent. Assuming this estimate to be true, it is noteworthy how very small these electrical particles are, compared with the atom of matter to which they are attached. If an electron is represented by a sphere an inch in diameter, the diameter of an atom of matter on the same scale is a mile and a half. Or if an atom of matter is represented by the size of this theater, an electron is represented on the same scale by a printer's full stop. It is well to bear this extreme smallness in mind in what follows.

An atom is not a large thing, but if it is composed of electrons, the spaces between them are enormous compared with their size—as great relatively as are the spaces between the planets in the solar system.

4. My next thesis is that these electrons or minute charged corpuscles can exist separately, for they can be detached from their atoms of matter at an electrode, not only in electrolytic liquids but also in gases, and when thus released from their thousandfold more massive atom, they fly away from the negative electrode with prodigious speed, because they are acted on by the same electrical propelling force as before, but now have hardly anything to move.

These isolated flying particles travel a long distance in rarefied gas, and are known as cathode rays. They were studied by Hittorf, Crookes, Lenard and others, both inside and outside vacuum tubes, and they are now known to be flung off spontaneously from many substances. When stopped suddenly by a massive obstacle, they give rise to the X-radiation discovered by Röntgen. At first these cathode rays were thought to be atoms of matter, though their extraordinary penetrating power rendered such a hypothesis difficult of belief, and caused Crookes to speak of them as matter in a fourth state. They are, however, certainly energetic bodies, being able to propel light windmills, to heat platinum to redness, and to charge an electroscope; they are also able to penetrate thin sheets of metal and to affect photographic plates or phosphorescent substances on the other side. They are not so penetrating, however, as are some of the Röntgen rays.

The final definite establishment of the fact that these flying particles are not atoms of matter, but are bits chipped off the atoms, fractions of an atom as it were, the same identical kind of bits being chipped off every kind of chemical atom, their mass always about one thousandth of that of a hydrogen atom, and moving under favorable circumstances with something not much less than the speed of light, is due to the researches of Professor J. J. Thomson and his coadjutors in the Cavendish Laboratory, Cambridge, and represents a long series of measurements devised and executed with consummate skill.

I have no time to go into detail concerning these important and elaborate and most interesting investigations. Suffice it to say that portions of them are due to your own Wykeham professor of physics, Professor Townsend, working in conjunction and collaboration with others, under the leadership of Professor J. J. Thomson; and that this whole series of Cavendish Laboratory researches may be said to constitute the high-water mark of the world's experimental physics during the beginning of this century.

5. I must not dwell upon the properties and powers of electrons, nor upon the experimental means by which these measurements were made, for it is far too large a subject. I must exhibit a few diagrams, and briefly summarize a few main facts.

Electrons have been shown to be shot off from any negatively charged body, especially from negatively electrified metals, when exposed to ultra-violet light.

When shot into a mass of air they ionize that air for a time, and render it electrolytically conducting; also of course they can discharge positively electrified bodies themselves, and can thus be most readily detected in small numbers.

Electrons in orbital motion have been shown to constitute the mechanism by which atoms are able to radiate light; and a great mass of semi-astronomical facts concerning these orbits and their perturbations have been obtained by immersing the source of light in a strong magnetic field, and observing the minute but very definite changes of spectra thereby produced: a branch of science with which the names of H. A. Lorentz, of Leyden, and Zeeman, of Amsterdam, will be inseparably associated.

In all these and other ways the electron has become a familiar object. It constitutes the ionic charge of matter. Multiples of it, but no fractions, are possible. Its mass, its charge and its speed have been frequently measured by different processes, and always with consistent results. It is the most definite and fundamental and simple unit which we know of in nature.

It has thus displaced the so-called atom of matter from its fundamental place of indivisibility. The atom of matter has been shown

capable of losing an electron, of having at least one chipped off it. The electron has been shown to possess in kind, though not in degree, the fundamental properties of the original atom of which it had formed a part; and it becomes a reasonable hypothesis to surmise that the whole of the atom may be built up of positive and negative electrons interleaved together, and of nothing else; an active or charged ion having one electron in excess or defect, but the neutral atom having an exact number of pairs. The oppositely charged electrons are to be thought of on this hypothesis as flying about inside the atom, as a few thousand specks like full stops might fly about inside this hall; forming a kind of cosmic system under their strong mutual forces, and occupying the otherwise empty region of space which we call the atom—occupying it in the same sense that a few scattered but armed soldiers can occupy a territory—occupying it by forceful activity, not by bodily bulk.

6. The hypothetical part of the statement about the size of an electron is the following. Whereas both the mass and the charge of an electron is known, it is not yet quite certain that the mass is *wholly* due to the charge. It is possible, but to me very unlikely, that the electron, as we know it, contains a material nucleus in addition to its charge, so in that case it need not be so concentrated, because a portion of its mass would be otherwise accounted for.

I say 'accounted for,' but it would be equally true to say unaccounted for. The mass which is explicable electrically is to a considerable extent understood, but the mass which is merely material (whatever that may mean) is not understood at all. We know more about electricity than about matter; and the way in which electrical inertia is accounted for electromagnetically and localized in the ether immediately surrounding the nucleus of charge, is comparatively clear and distinct.

There *may* possibly be two different kinds of inertia, which exactly simulate each other, one electrical and the other material; and those who hold this as a reasonable possibility are careful to speak of electrons as 'corpuscles,' meaning charged particles of matter of extremely small size, much smaller than an atom, consisting of a definite electric charge and an unknown material nucleus; which nucleus, as they recognize, but have not yet finally proved, may quite possibly be zero.

The chief defect in the electrical theory of matter at present is that the *positive* electron, if it exists, has never yet been isolated from the rest of an atom of matter. It has never been found detached from a mass less than the hydrogen atom; whereas the negative electron is constantly and freely encountered flying about alone, its mass being little more than the thousandth part of an atom of hydrogen.

Until a positive electron can be similarly isolated, the hypothesis that an atom is really composed solely of electricity, that is to say, of equal quantities of positive and negative electricity associated together in a certain grouping of little bodies, each of which is nothing more than a concentrated charge of electricity of known amount, must remain a hypothesis.

7. It is a fascinating guess that the electrons constitute the fundamental substratum of which all matter is composed. That a grouping of say 700 electrons, 350 positive and 350 negative, interleaved or interlocked in a state of violent motion so as to produce a stable configuration under the influence of their centrifugal inertia and their electric forces, constitutes an atom of hydrogen. That sixteen times as many, in another stable grouping, constitute an atom of oxygen. That some 16,000 of them go to form an atom of sodium; about 100,000 an atom of barium; and 160,000 an atom of radium.

On this view all the elements would be regarded as different groupings of one fundamental constituent. Of all the groupings possible, doubtless most are so unstable as never to be formed; but some are stable, or at least relatively stable, and these stabler groupings constitute the chemical elements that we know. The fundamental ingredient of which, on this view, the whole of matter is made up, is nothing more or less than electricity, in the form of an aggregate of an equal number of positive and negative electric charges.

This, when established, will be a unification of matter such as has through all the ages been sought; it goes further than had been hoped, for the substratum is not an unknown and hypothetical protyle, but the familiar electric charge. Nevertheless, of course, it is no *ultimate* explanation. The questions remain, what then is an electric charge? what is the internal structure and constitution of an electron? wherein lies the difference between positive and negative electricity? and what is their relation to the ether of space? Definite questions these, and doubtless some day answerable; indeed, powerful methods of attack on this position have been already contrived by Dr. J. Larmor and others; but they are questions of a higher order of difficulty than those which occupy us to-day, and it must remain for a future Romanes lecturer to report progress in these directions, whenever adequate progress has in fact been made.

8. That is the end of the first half of my lecture; and six months ago that, somewhat expanded, might have been the whole of it, because the next portion would have seemed too fanciful; but discoveries have been made, chiefly in France and in Canada—some of the most striking of them within the present year—which remove the treatment of the next part of my subject from the realm of fancy to the region of probability, and justify my proceeding further with some of

the theoretical consequences deducible from an electric theory of matter.

I referred above briefly to the origin of radiation, saying that by the method of applying a powerful magnet to a source of light, and examining the minute perturbations in the lines of the spectrum thus produced, it had been proved that the real source of radiation was an electric charge in rapid orbital motion; and I now go on to say that by careful measurement of the amount of perturbation it has been definitely proved that it is our friends the negative electrons, with a mass about one thousandth of the smallest known atom of matter, that are responsible for the excitation of ether waves or the production of light. Larmor and others have indeed shown mathematically that whenever an electric charge is subject to acceleration, an emission of some amount of radiation is inevitable, by reason of the interaction of its electric and magnetic fields; and it is probable that there is no other source of light or radiation possible except this change in the motion of electrons. It is known, for instance, that the violent acceleration or retardation of electrons when they encounter an obstacle is responsible for the excitation of Röntgen rays. All light, and all the Hertz waves or pulses employed in wireless telegraphy, are due to electric acceleration, and the greater the rate of change of velocity the more violent is the radiation emitted.

The charge may oscillate, as in a Hertz vibrator, or it may revolve, as in a source of ordinary light such as a sodium flame. In order to emit perceptible radiation by revolving, it must revolve with extreme speed in a very small orbit, so that its rate of curvature or centripetal acceleration may be considerable; for it is on the square of the value of the average acceleration that the energy of radiation depends.

9. All this is of the nature of a definite and certain thesis; but now we are going to apply it to our hypothesis that the atom of matter is either wholly or partially composed of electrons in a state of vigorous motion among themselves. Such revolving or vibrating electrons are subject to acceleration, either radial or tangential, and must therefore to a greater or less extent necessarily emit radiation; it becomes natural to inquire whence comes the energy that is radiated away.

Now in ordinary familiar cases it is the irregular agitation of molecules which we call 'heat' that is being radiated away; and in that case the result is a mere cooling, or diminution of the molecular agitation, which can readily be made up by receipt of similar energy from the enclosures or from surrounding bodies; or, if not made up, it can produce the ordinary well-known effects of 'cold.' But to the motion of the internal parts of an atom the ideas of heat and temperature do not apply. The atom, if it lose energy, must lose what is to it an essential ingredient; and hence this inevitable radiating power

of the constituents of an atom seemed to constitute a difficulty, for it suggested that an atom of matter was not really a permanent and eternal thing, but that it contained within itself the seeds of its own decay and ultimate dissipation into the separate electrons of which it was composed. The process might indeed be exceedingly slow, the radiation loss might be almost imperceptible, but, in so far as an atom is composed of revolving electrons, it is inevitable that radiation of energy must go on from it, and that this must in the long run have some perceptible degenerative result.

10. That result has quite recently, I believe, been experimentally discovered, and is a part of the phenomenon known as 'radio-activity.'

So now we come to the most remarkable and probably the most interesting step of all.

The phenomenon of spontaneous radio-activity, discovered first by Becquerel in uranium and thorium, and greatly extended by the brilliant chemical researches of M. and Mme. Curie which resulted in the discovery of radium (they are coming to London next week, and will be received, I expect, royally by the scientific world), was at first supposed to consist in the emission of a sort of X-rays or ether pulses; and was subsequently assumed to consist chiefly in the bodily emission of electrons, which were shot off from the radio-active substance as they are from a negative electrode in a vacuum-tube, or as they are in air when ultra-violet light falls upon clean negatively charged surfaces.

As a matter of fact both these modes of radiation—the wave form and the corpuscular form—are emitted by radio-active bodies, but they turn out to be of subordinate importance, and must be regarded as secondary or subsidiary results of the main phenomenon.

The main fact of radio-activity has been shown by Professor Rutherford, of Montreal, in a paper published in the month of February this very year, to consist in the flinging away with great violence of actual atoms of matter: atoms electrified indeed, but not negatively like electrons, and not small or penetrating like them, but full-sized atoms, such as are easily stopped by a thin sheet of metal, or even by a sheet of paper—atoms which are positively charged and possessed of a remarkable amount of energy, ionizing the air which they bombard to an extraordinary extent, and likewise generating quite a perceptible amount of heat wherever they strike; producing indeed a flash when they strike a suitable target, as Crookes has shown, quite like the impact of a cannon-ball on an armor-plate. Their speed, indeed, far exceeds that of any cannon-ball that ever existed, being as much faster than a cannon-ball as that is faster than a snail's crawl; a hundred times faster than the fastest flying star, these atomic projectiles constitute the fastest moving matter known. This furious

bombardment from a radio-active substance continues without intermission and apparently without sign of diminution or cessation. There is every reason to believe that a minute scrap of radium, scarcely perceptible to the eye, may go on emitting these energetic projectiles for hundreds of years.

11. At first sight the fact that it is merely atoms of matter which are being flung off by most radio-active substances, and that ethereal and other effects are subsidiary to this emission of substance, seems to lessen the interest attaching to the phenomenon, reducing it to something of merely chemical importance, and suggesting a resemblance to scent or other volatilization from solid bodies. But Professor Rutherford, with great skill, succeeded in determining approximately the atomic weight of the utterly imperceptible amount of substance thrown off, as well as its speed, and found that it was not by any means the radio-active substance itself which was evaporating, but something quite different.

Plainly, if an elementary form of matter is found to be throwing off another substance, it becomes imperative to inquire what that substance is, and what it is that is left behind. Now the atomic weight of radium, or of thorium or uranium, or of any known strongly radio-active substance, is very high, in each case over two hundred times the atomic weight of hydrogen, whereas the atomic weight of the substance flung off appears to be more nearly of the order one or two; in other words, the substance thrown off is more likely to be either hydrogen or helium than it is likely to be radium. It is just possible that the inert chemical elements are by-products of radio-activity.

Now clearly here is a fact, if fact it be, of prodigious importance. Undoubtedly the measurements require confirmation, but for myself I see no reason to doubt them, at least as regards their order of magnitude. The atomic weight of radium being say 225, and that of the projected portion being say 2, the residue must represent by its atomic weight the difference between the heavy atom of the original substance and that of the light atom or atoms which have been flung away: unless indeed it be assumed, as it will almost certainly be assumed by some skeptical chemists, those who derided argon and other chemical discoveries when made in a physical manner, that the substance flung away is some foreign ingredient or impurity—a hypothesis, I venture to say, already strongly against the weight of available evidence.

The substance left behind in the pores of the radio-active substance has been examined even more completely than the projected portion: it is volatile, it slowly diffuses away, and it behaves like a gas. It can be stored in gas-holders when mixed with air, for in amount it is quite imperceptible to all ordinary tests; and yet it can be passed through pipes and otherwise dealt with. It condenses not far above the tem-

perature of liquid air, and it is itself radio-active, but in such a way that its power decays rapidly with time. Its radio-activity seems to consist likewise in throwing away part of itself and leaving yet another residue, likewise radio-active; and one of the residues so left seems ultimately to pitch away electrons simply instead of atoms of matter. It is not to be supposed that thorium and radium and uranium all behave alike in details. The emanation of one may lose its activity rapidly, and give rise to another substance which retains its power for some time; the emanation of another element may last some time and generate a substance whose activity rapidly decays; but into these details it is not now the place to go.

12. Assuming the truth of this strange string of laboratory facts, we appear to be face to face with a phenomenon quite new in the history of the world. No one has hitherto observed the transition from one form of matter to another: though throughout the Middle Ages such a transmutation was looked for. The transmutation of elements has been suspected in modern times on evidence vaguely deducible by skilled observers from the spectroscopic details of solar and stellar appearances. The evolution of matter has likewise been suspected by a few chemists of genius: it was perceived, on the strength of Mendelejeff's law, that the elements form a kind of family or related series, and it was surmised that possibly the barriers between one species and the next were not absolutely infrangible, but that temporary transitional forms might occur. All this was speculation; but here in radio-active matter the process appears to be going on before our eyes. Professor Rutherford and Mr. Soddy, who in Canada during the present year have worked hard and admirably at the subject, have adduced facts which point clearly in this direction; and they initially describe what appear to be the first links of a chain of substances, all produced in hopelessly minute quantities reckoned by ordinary tests, but which yet by electrical means can easily be detected, and their boiling-points and other properties investigated. Moreover, the investigators of these strange substances are able to dissolve and precipitate, and perform ordinary chemical operations on, these utterly imponderable and hopelessly minute deposits of radio-active substances, because of the powerful means of detection which their ionizing power puts into our hands —even a few stray atoms being able by their ionizing power to discharge an electroscope appreciably.

13. Thus then it would appear that our theoretical conclusion concerning the inevitable radiation and loss of energy from electrically constituted atoms of matter, a loss which must involve them in necessary change and dissolution, meets with quite unexpectedly rapid confirmation, and it is for that reason that I feel willing to accept tentatively and as a working hypothesis this explanation of radio-activity.

It represents a fact previously wanted on theoretical grounds. For how is radio-activity to be explained? It looks as if the massive and extremely complex atoms of a radio-active substance were liable to get into an unstable condition, probably reaching this condition whenever any part of it attempts, or is urged, to move with the velocity of light. I have shown elsewhere* that the mere fact of radiation will act as a resisting medium and increase the speed of the particles automatically, on the same principle that a comet would be accelerated if it met with resistance; since the inverse square law applies to electrical central forces. Electrical mass is not strictly constant: it is a function of speed, but in such a way that it is practically constant until the velocity of light is very nearly attained. That is a critical velocity, which apparently can not be surpassed. When this critical speed is reached, any electrified body becomes suddenly of infinite mass, and something is bound to happen. What that something is, it is not easy theoretically to say; but the partial or incipient disintegration or dissociation of the atom, and the flying away of a portion with a speed comparable to that of light, is no unlikely result.

Out of the whole multitude of atoms, even of the atoms of a conspicuously radio-active substance, it is probable that only a very few get into this unstable or critical condition at any one time; perhaps not more than one in a million million; nevertheless, just as occasional though rare encounters take place in the heavens, followed by the blaze of a new and temporary star, so, though probably not by the same mechanism, here and there a few out of the billions of atoms in any perceptible speck of radium arrive in due time at the unstable condition, and break down into something else, with energetic radio-activity during the sudden collapsing process; emitting in the process of collapse not only the main projected substance, but likewise also a few electrons and those X-rays which always accompany a sudden electric jerk or recoil. And the X-rays so emitted are of the most penetrating kind known, being able to pass through an inch of solid iron in perceptible quantity.

14. The hypothesis concerning radio-activity which is now in the field, then, is that a very small number, an almost infinitesimal proportion, of the atoms are constantly breaking up; throwing away a small portion, say one per cent. of themselves, with immense violence, at about one tenth of the speed of light; the remainder constitute a slightly different substance, which, however, is still extremely unstable, and therefore radio-active, going through its stages with much greater rapidity than the radium itself, because practically the whole of it is in the unstable condition, and so giving rise to fresh and fresh products

* See *Nature* for June 11, 1903.

of its own decay, till a comparatively stable state is reached, or till the process passes beyond our means of detection.

Roughly, the process may be likened in some respects to the condensation or contraction of a nebula. The particles constituting a whirling nebula fall together until the centrifugal force of the peripheral portions exceeds the gravitative pull of the central mass, and then they are shrunk off and left behind, afterwards agglomerating into a planet; while the residue goes on shrinking and evolving fresh bodies and generating heat. A nebula is not hot, but it has an immense store of potential energy, some of which it can turn into heat, and so form a hot central nucleus or sun. A radium atom is not hot, but it too has a great store of potential energy, immense in proportion to its mass, for it is controlled by electrical, not by gravitational forces; and just as the falling together of the solar material generates heat, so that a shrinkage of a few yards per century can account for all its tremendous emission, so it has been calculated that the collapsing of the electrical constituents of a radium atom, by so little as one per cent. of their distance apart, can supply the whole of the energy of the observed radiation—large though that is—for something like 30,000 years.

15. It does not follow that the life of a piece of radium is as great as that; the data are uncertain at present, but there is absolutely no ground for the popular and gratuitous surmise that it emits energy without loss or waste of any kind, and that it is competent to go on for ever. The idea, at one time irresponsibly mooted, that it contradicted the principle of the conservation of energy, and was troubling physicists with the idea that they must overhaul their theories—a thing which they ought always to be delighted to do on good evidence—this idea was a gratuitous absurdity and never had the slightest foundation; but the notion that radium was perhaps able to draw upon some unknown source or store of energy, without itself suffering loss, was a possibility which has not yet wholly disappeared from some minds. Sir W. Crookes, for instance, suggested that it might somehow utilize the most quickly moving atoms of air, after the fashion of a Maxwell demon—a possibility that should always be borne in mind as a conceivable explanation of the power of some living organisms. It is much more reasonable to suppose, however, that radium and the other like substances are drawing upon their own stores of internal atomic energy, and thereby gradually disintegrating and falling into other, and ultimately into more stable, forms of matter.

Not that it is to be supposed that even these are finally and absolutely stable: these too are subject to radiation loss, and so must be liable to decay; but at a vastly slower rate, perhaps not more than a few hundred atoms changing and diffusing away each second—a process

utterly imperceptible to the most delicate weighing until after the lapse of millions of years; so that for all practical purposes, and for times such as are dealt with in cosmic history, they are permanent, even as the solar system and stellar aggregates appear to us to be permanent. Yet we know that all these systems are in reality transitory, as terrestrial structures like the pyramids or as the mountains and the continents themselves are transitory: of all these things it may be said that in any given form they have their day and cease to be. But whereas geological and astronomical configurations pass through their phases in a time to be reckoned in millions of years, the active life of a solar system covering perhaps no very long period, it is probable that the changes we have begun to suspect in the foundation stones of the universe, the more stable elemental atoms themselves, must require a period to be expressed only by millions of millions of centuries. For in such a time as this, at the rate of a hundred atoms per second, a bare kilogram—a couple of pounds only—of matter, even of heavy matter, would have drifted away; not so much indeed—a couple of ounces more likely. And yet this period is a million times the estimated age of the earth.

16. If we allow ourselves to speculate, on the strength of the slender experimental evidence as yet forthcoming, instead of waiting, as to be wise we must wait, for confirmation and thorough examination of the facts, we should say that the whole of existing matter appears liable to processes of change, and in that sense to be a transient phenomenon.

Somehow, we might conjecture, by some means at present unknown, it takes its rise: electrons of opposite sign crystallizing or falling together, perhaps at first into a manifestly unstable form; these forms then pass on from one into another, going through a series of transitional states, and abiding for a long time in those configurations which are most stable; giving a process of evolution inconceivably slow in its later stages, comparatively rapid in its early ones: and yet not so rapid, even in a substance like radium, but that its life as such may be reckoned by thousands of years.

If such a transitory existence is ever established for the forms of matter as we know them, it by no means follows that the process goes on in one direction only, or that the total amount of matter in the universe is subject to diminution. There may be regeneration as well as degeneration.

The total amount of radio-activity in a substance is singularly constant. If the radio-active portion is removed, a fresh supply makes its appearance at a measured rate, that rate being expressible by a decreasing geometrical progression, and being precisely equal to the rate at which the power of the removed portion decays.

Whether the total amount of matter in the universe is constant likewise, as much disappearing at one end by resolution into electrons as is formed at the other end by their aggregating together, is at present quite unknown; and indeed it is clear that we have now become far immersed in the region of speculation. Nevertheless, it is speculation not of an illegitimate character, for it is very consistent with all that we know about the rest of the material universe.

Astronomy tells us that the cosmic scheme, though it looks permanent, is subject to constant flux. In the sky we see solar systems and suns in process of formation by aggregation out of nebulæ; we see them rise in brilliancy, maintaining a number of planets in health and activity for a time, and then slowly become subject to decay and death. What happens after that is not certainly known; it may be that by collision a nebula may be reconstituted and the process started again; though so long as there is only a force of one sign at work (gravitation only) it would seem that ultimately the regenerative process must come to an end. The repellent force exerted by light upon small particles, however, must not be forgotten; it can overcome gravitation when it acts on small enough bodies; and there are other possibilities. Among the parts of an atom certainly the forces are conspicuously not of one sign; inside an atom there exist both attractive and repulsive forces; the resolution of an atom into its electron constituents, and the aggregation of these constituents into fresh atoms, are both perfectly thinkable. All we have to do is to ascertain by careful and patient investigation what really happens; and my experience has led me to feel sure of this, that whatever hypotheses and speculations we may frame, we can not exceed the reality in genuine wonder; and I believe that the simplicity and beauty of the truth concerning even the material universe, when we know it, will be such as to elicit feelings of reverent awe and adoration.

THE TRAINING OF A PHYSICIAN.*

By President DAVID STARR JORDAN,
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IN mediæval times the physician was a compound of sorcerer and priest; distrusted by sorcerers lest he disclose the secrets of their trade; distrusted by priests lest he undo their work with the heathenism of sorcery. His operations were mystic, out of relation to cause and effect, for it was widely believed that the forces of the body are independent of bodily structures, and that sickness was a blow from the outside, a penalty for sin or lust or unbelief, not the expression of bodily derangement.

So the physician dealt with words as much as with medicines. Many Latin words held a magic power. By their use he could call up spirits, mostly evil, could put man to sleep or make a broomstick alive. Lest he carry these things too far, there were statutes forbidding the physician to act save in the presence of a priest. Besides words, he dealt in simples; each drug having potency over its particular disease. These drugs he would know by their signatures, the mark of the Almighty on them indicating their use. Thus a scrofulous-looking root would cure scrofula, snake-head or snake-root would cure snake bite; blood-root with red juice was good for the blood; celandine with yellow juice was marked for jaundice; liver-wort with liver-shaped leaves would heal the liver; eye-bright with an eye-spot in the flower would heal the eyes; bear's grease from hairy bears would cure baldness; a hair of the mad dog would relieve its venom. A red rag would cure inflammations. A drug which would give a headache would cure it. A long series of fancies and superstitions, which find their natural continuance in the electric belts and patent medicines of to-day.

Surgery was despised by medicine, and the little which was practised fell to the lot of barbers; with dirty knives and reckless hands surgery ended in gangrene and blood poisoning.

The success of the physician lay largely in the mystery of his operations, his Latin words and the red and blue flames which danced about the broths he concocted.

Meanwhile sanitation and diet were regarded as contrary to religion. Even the taking of medicine was sometimes forbidden as being a scheme to thwart God's purposes. Besides all this, the words

* Abstract of address, Cooper Medical College Commencement.

of the great physician, Galen, became the court of final appeal, and his ignorance marked the limit of all medical knowledge.

Yet there were great physicians in those days, martyrs and saints who should rank with the noblest, men who tried to know the truth and to act in accord with it. Roger Bacon was on the verge of discovering the secret of contagious disease and its prevention by inoculation and sanitation. Fourteen years in prison prevented all this.

Vesalius in these days was the founder of anatomy. Dissection of human bodies was prohibited as sacrilegious, the work of sorcerers and dangerous, as the supposed resurrection bone, the nucleus of the rising body, might be injured or destroyed by careless handling. Vesalius haunted gibbets and charnel houses, for the waste of human bodies. He hoped especially to find through dissection the secret of the Black Death. The personal physician of Charles V., he had powerful protection in his early work, but he fell at last under the mean bigotry of Philip II. "He was not lost," says President White. "In this century a great painter has again given him to us. By the magic of Hamann's pencil Vesalius again stands on earth and we look once more into his cell. Its windows and doors, bolted and barred within, betoken the storm of bigotry which rages without; the crucifix, toward which he turns his eyes, symbolizes the spirit in which he labours; the corpse of the plague-stricken beneath his hand ceases to be repulsive; his very soul seems to send forth rays from the canvas, which strengthen us for the good fight in this age."

Those who destroyed Vesalius did so in the name of religion. It was believed that 'diseases are sent as punishment; who interferes with them breaks God's commandment and is God's enemy.'

This belief checked the growth of medicine even so late as fifty years ago when Simpson first used anæsthetics in obstetrics. This was held to violate the command: 'In sorrow shalt thou bring forth children.' To doubt the prevalent theory of disease was to doubt all religion and to be a foe to Christianity. No wonder there were physicians who doubted; no wonder that it was declared on high authority: 'When three physicians meet, there are two atheists,' if by atheist was meant all who believe that diseases are produced by natural causes.

So long as medicine rested on a basis of mystery, symbolism and philosophy, its limits set by the words of Galen, so long its progress was marked by martyrs, not by its successful practitioners. Even a hundred years ago success in medicine was largely quackery. Imaginary diseases were treated and in fantastic ways. In Napoleon's time, the itch was a prevalent disease in the higher classes, a disease which they did not know how to cure. At this time, most internal ills were diagnosed as 'Gale repercutée,' 'Itch struck-in,' and the arch

medical performer of his time, Hahnemann, is reported to have said that two thirds of all diseases have this origin, 'they are the itch struck-in.' But a little knowledge of entomology with a hand lens has abolished the disease. Itch no longer 'strikes in' and nothing is more easily cured. Meanwhile the internal disorders called itch are being treated each in its own way.

The progress in medicine has been in proportion to its dependence on science and the scientific method. Science is human experience tested and set in order. Progress through science means simply learning through experience and taking pains to sift and test experience.

I need not speak of the details of this progress. Surgery is applied anatomy; antisepsis is applied bacteriology; pharmacology is applied chemistry; with instruments of precision, wonderful progress is made in the interpretation of experience. There is nothing in the history of science more suggestive than the simultaneous lights thrown on bacteria and microbes from many quarters at once. Lister with his clean knives and antiseptic surgery, Bastian trying to prove the spontaneous generation of infusoria in vegetable broths; Tyndall trying to clear his tubes from floating particles in the air which break up the rays of light, Pasteur with his blighted silk-worms—all these men were at work at the same problem—each with his varied instruments of precision, and the final result of all, the theory of fermentation, putrefaction, antisepsis and contagious diseases. Our knowledge of the minute organisms all about us, as real, as helpful or as harmful as the larger creatures of the earth, but the whole beyond the reach of the unaided senses.

With this knowledge, we have a new birth of the art of medicine. When we know our enemies, we can fight them intelligently. The progress of medicine, its achievements and discoveries being granted, how shall we teach it?

There should be advance in methods of teaching as well as in methods of gaining and testing facts. In the old days we had the method of apprenticeship. The little doctor saw what the big one did and followed his method. He learned to say the magic word, to make the magic passes, to brew the magic drug, to say more than he knows and to know more than he says.

In the ancient universities, the lecture was an exercise in dictation, the student taking word for word the wise phrases of the master. The ancient wizardry still prevails in some of our forms of medico-religious healing; the ancient belief in simples and signatory remedies, in our patent medicine trade. With ignorant people, the mysteries of

ignorance are valued above wisdom. To value wisdom is already to be wise.

The physician of to-day is not a priest nor a sorcerer. His place is rather that of an engineer. One who understands the make-up of the human mind machine, tries to keep it in order and faithfully repairs it when its parts are out of place. He knows that each effect has a cause, none the more mysterious because it must be sought with instruments of precision. He regards pain as a warning, not as a punishment. It is a sign that a screw is loose somewhere, and were it not for this warning we should not be sure to make it good.

In the continental universities of Europe, the teaching of medicine has been from the first a university function. The faculty in medicine has been one of the primary divisions of the university. The teaching of medicine has kept pace with the instruction in law, philosophy and science, under the same general influences, and with the same methods of control. In England, medical instruction has been more or less divorced from the university. It has been rather a function of medical associations and hospitals.

The American college had its origin in English models. Like the colleges of Oxford and Cambridge, it was more or less under ecclesiastical control, its first purpose being to develop clergymen and gentlemen, professional training being outside its scope and purpose. Thus the medical school in America arose through associations of physicians, wholly apart from the college system.

But the same argument which justifies common schools, high schools and state universities at public expense, applies to medical schools also. It is cheaper for a state, and infinitely better for it, to educate its own physicians than to tolerate uneducated ones. Better to educate its doctors and hire them afterwards than to be the prey of the quack, the impostor, the nostrum vendor and the almanac. This was the view of the founders of the University of Michigan, the first state college to devote itself frankly to the service of the state, regardless of tradition, regardless of what other states and institutions may be doing.

Other states followed the example of Michigan, establishing schools of law and medicine and of other professions. Still others, as Indiana, adopted a contrary view, and for a time refused to appropriate money to 'help young men into these easy professions.'

Meanwhile, in default of endowment and public support, private interest founded medical schools where they were needed. Later, for purposes of advertising or of money-making, other schools of lower standards were established where they were not needed. Hence we have finally medical schools of every grade of honor and of dishonor,

some ranking with the best in the world, others periodically raided by the police.

Our democratic custom is to let every school shift for itself. In the eyes of the law, every doctor is a doctor, if he has earned or bought a diploma somewhere—herb-doctor, corn-doctor, faith-healer, electric-healer, all kinds of healers, pass as doctors, and the people must choose for themselves.

Doubtless science wins in the long run. The honest school and the honest man are the final winners, but there is a prodigious amount of waste and suffering before the public knows the difference between surgeons and bloodsuckers.

More and more the honest medical schools are brought into touch with the university. Around the university the tested educational machinery tends to center. Sound instruction in medicine demands a broad base of science—physiology, anatomy, chemistry, histology, bacteriology and above all the methods of scientific research. All these are fundamental to any real knowledge of the art of medicine. All these are essentials in the work of the modern university. The medical school is giving these up to the institutions which can teach them for their own sake, and therefore teach them better. This change shortens the medical course, by making it longer, by placing it on a broader and higher foundation. The medical school, then, teaches the application of science, the science itself being studied elsewhere. There is a tendency toward an easy transition from the one to the other, so that the student can not tell when he began to study medicine.

In the old days the transition was abrupt, and the medical student learned applications of science before he had the faintest idea of science itself. He was thrown at once into a topsy-turvy world, where decencies did not count, where grewsome honors were everyday affairs, and where all ordinary restraints were cast aside. Hence he kept his tobacco in the skull of a murderer, wore a resurrection bone for a scarf-pin, and was the most reckless, lawless, irreverent of all students, careless of temperance, sanitation and chastity. Of all students, thirty years ago, the medical student had deservedly the reputation of being the worst.

Leaving out ill-equipped or temporary schools, the American medical school of the future will have one or the other of two great purposes. The one is typified perhaps by the Medical School of Michigan. It will take the profession as it is and raise it as a whole. So many men will be doctors, so many will be lawyers in Michigan. Let us take them as we find them and make them just as good lawyers and doctors as we can. Let us not drive them away by requirements they can not or will not meet, but adjust the work and conditions to the

best they can meet, the best standards winning in the long run and carrying public opinion with them.

The other ideal is perhaps typified by Johns Hopkins University. Let the university medical school deal with the exceptional man of exceptional ability and exceptional training. Give him special advantages; send out a limited number of the best physicians possible, and raise the standard of the profession by filling its ranks with the best the university can send.

The one ideal or the other will be, consciously or not, before each professional school which strives to be really helpful. It is not for me to say which is best. The one purpose naturally presents itself to state institutions, or to institutions dependent on appropriations or patronage. The other is more readily achieved by institutions of independent endowment. It is a matter of economy that all schools should not be alike in this respect.

What should be the regular requirement for entrance to the medical school? The university influences tend to push requirements up. The influence of the counting room and the desire to show numbers tend to push them down. Shall men go into medicine from the common school, from the high school; from the middle of the college course; from its end? Or shall we, with Johns Hopkins, demand not only a college course, but one which contains all the sciences fundamental to the study of medicine.

For the second type of schools, the schools which aim at the highest professional success, the latter is the natural requirement, the only one worth considering. For the schools which would elevate the profession as it is, the facts must be met half way. We know that a common school preparation is farcical, yet great physicians have been made with this as the basis of education. Such are men who can learn from their own experience and interpret the experience of others. No matter how wide the door of the colleges, there are some men so strong as to be capable of educating themselves.

The high school course gives a certain breadth of culture. The high school of to-day is as good as the college of forty years ago, so far as studies go. It misses the fact of going away from home and of close relation with men of higher wisdom and riper experience than our high schools demand in their teachers.

It takes a broader mental horizon to be a physician than merely to practise medicine. For those who want the least education possible, they can get along with very little; they can omit the college. But for large-minded, widely competent men, men fit for great duties, not a moment of the college course can be spared. Whether to take a college education or not, depends on the man—what there is in him—

and on the course of study. There is no magic in the name of college, and there is no gain in wrong subjects, work shirked, or in right subjects taken under wrong teachers. Studies, like other food, must be assimilated before they can help the system.

The great indictment of the college is its waste of the student's time; prescribed studies taken unwillingly; irrelevant studies taken to fill up, helpful studies taken under poor teachers, any kind of studies taken idly—all these have tended to discredit the college course. Four years is all too short for a liberal education, if every moment be utilized. Two years is all too long if they are spent in idleness and dissipation, or if tainted by the spirit of indifference.

The spirit of the college is more important than the time it takes. The college atmosphere should be a clean and wholesome one, full of impulses to action. It is good to breathe this air, and in doing so, it matters little whether one's studies be wholly professional, half professional, or directed towards ends of culture alone.

The practical evolution of this matter will be this: The medical school for the exceptional student will require a college course of science with physiology and chemistry as the leading subjects, other sciences, with German and French, being necessary factors. The state medical colleges and those of similar purposes will content themselves with a minimum of two years of college work, along semi-professional lines, the preparatory medical course.

In city colleges where the students live at home, traveling back and forth on street cars, a college atmosphere can not be developed. In these institutions, as a rule, the college work is perfunctory, its recitations being often regarded as a disagreeable interruption of social and athletic affairs. As a rule, higher education begins when a man leaves home to become part of a guild of scholars. The city college is merely a continued high school, and with both students and teachers there is a willingness to cut it as short as possible, so that the young men can 'get down to business.' In institutions of this type, the professional school forms a sharp contrast to the college in its stronger requirements and more serious purpose. In other types of college, it is the general student who does the best work. In many of them the professional departments are far inferior in tone and spirit to the general academic course.

It becomes, then, a question of the college itself, how long a student should stay in it. If the academic requirements are severe, just and honest, if the idler, the butterfly, the blockhead and the parasite are promptly dropped from the rolls, if the spirit of plain living and high thinking rules in the college, the student should stay there as long as he can, and if possible take part of his professional work under

its guidance. The nearer the teacher, the better the work. The value of teachers grows less as the square of their distance increases. If the college course is a secondary matter, with inferior teachers talking down to their students lessons prescribed because the faculty cares too little for the individual man to adapt its courses to his needs, an atmosphere of trifling, or no atmosphere at all, the sooner the student gets into something real, the better. A good university may develop in a great city, a good college can not, because teachers and students are all too far apart.

In this matter the college degree is only an incident. It is the badge of admission to the roll of alumni, a certificate of good fellowship, which always means a little and may imply a great deal. But the degree is only one of the toys of our educational babyhood, as hoods and gowns represent educational bib and tucker. Don't go out of your way to take a degree. Don't miss it because you are in too great a hurry. For the highest professional success, you can afford to take your time. It takes more provision for a cruise to the Cape of Good Hope than for a trip to the Isle of Dogs.

AMERICAN TITLES AND DISTINCTIONS.

By Professor W. Le CONTE STEVENS,
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THOMAS CARLYLE is credited with the statement that England has a population of twenty or thirty millions—'mostly fools.' The definition of fool is not given. If the word means anything else than an expression of dislike it is that the unfortunate man who bears such a title is so deficient in intelligence or in good judgment as to be worthy of unenviable distinction. But a distinguished man, whether his distinction be good or bad, stands out among his fellows in some way. It is impossible for the larger part of any mass of human beings composing an organized body, whether the students of an educational institution, or the devotees of fashionable society, or the population of a great nation, to be distinguished. The mere fact that in such a body a majority possesses qualities which might otherwise confer distinction upon an individual destroys the possibility of preeminence based on such possession. Every one recognizes that Carlyle's epigram expressed no objective truth, but that he displayed only the acidity and peevishness of one whose influence was perceptibly waning.

Epigram is never quite consistent with truth. It may contain enough mixture of truth with falsehood to command the momentary assent of even a thoughtful man. Its essential feature is brightness rather than solidity, and it arrests the attention when accuracy fails to attract. A French writer who has recently passed away, Paul Blouët, visited America some years ago, and the inevitable book of impressions was the natural consequence. His fondness for epigram had amused many readers of a previous book entitled 'John Bull and his Island.' The first chapter of 'Jonathan and his Continent' began with the following words in imitation of Carlyle: 'The population of America is sixty millions—mostly colonels.' In a subsequent chapter he emphasized this idea with the statement, "Every American with the least self-respect is colonel or judge; but if you should discover that your interlocutor is neither colonel nor judge, call him 'Professor,' and you are out of the difficulty." This implication that professors belong by exclusion to a class without the least self-respect may be unwelcome to some of the unfortunates who are compelled to carry this mark of Cain; but there is enough truth in the Frenchman's epigram

to suggest the question whether democratic America is not the richest in titles of any country in the world; and, if so, why should it be so?

Let an American visit Germany or Russia; any country of continental Europe where the encroachment of free institutions upon the military control of society is less marked than among our people. The first feature that obtrudes itself is that soldiers in uniform are to be seen in every important town. The visitor is required to register at police headquarters and answer a variety of questions, rational and irrational, about his present, past and probable future. He learns that titles of all kinds, but especially military titles, are protected by law. The man who calls himself a colonel, or allows his friends to call him so, is soon required to prove his claim to the title. Where is his uniform? If he is a foreigner, why did he not report his rank at the police registration office? Is he not a suspicious character whose actions must be watched? If he is a native jackdaw trying to wear borrowed plumage he is lucky if he avoids arrest. The professor, moreover, is an officer of the government, whose salary is paid from the public treasury, so far as his income is derived from a salary. Any one who assumes the title without official sanction does so at his own peril. To hold such an office is presumptive evidence of marked ability, and it carries with it a claim to social deference that is universally accorded. No colonel or professor in Germany can exist as such without having stood tests of special training that prove him an educated man. No such title comes by inheritance or courtesy. It means much and its value is great. No such prize can be stolen by the unworthy, for danger attends the violation of law where popular sentiment sustains the military power that ensures its enforcement.

It must not be inferred, however, that all titles in continental Europe have retained the meaning or the importance originally attached to them. Everything depends upon the consideration whether the title has been directly acquired or has been inherited. In a German university where the present writer spent some time the physical laboratory assistant, whose duties were exclusively mechanical, was a count whose inheritance seemed to be limited to his title. In the duchy of Mecklenburg a traveler has found a count for landlord of the village inn, a countess for landlady, young counts filling the places of hostler, waiter and bootblack, and countesses for cooks and chambermaids. Indeed, in one village all the inhabitants except four were found to be of noble birth. America therefore has by no means a monopoly of cheap titles.

It would perhaps be interesting to trace in detail the evolution of titles with the development of society; but such a field is too extensive. Originally a name or title was merely the suggestion of an association. 'Young-man-afraid-of-his-horse' was a Sioux Indian whose fame might

have been local only had he not come too near to the American newspaper correspondent. The desire of the weak to appease or flatter the strong has been the most fertile origin of titles. In darkest Africa the king is addressed by such names as the 'Lion of Heaven,' the 'Bird who eats other birds,' or 'Thou who art as high as the mountains.' A proper name easily becomes applied to a family or a class, and is thus handed down to successive generations. Nothing is easier for the savage than to apply superhuman attributes to a successful warrior and to deify him after his death. After natural slumber he wakes with renewed strength. The slumber of death seems merely deeper and longer than usual, and it is easy to believe that latent power has not been lost. The warlike father of his tribe is transformed into the god of his tribe. The grand lama of Thibet does not wait for death, but is worshiped as 'God the Father' by his obsequious subjects. The ruler, whether visible or invisible, is 'father,' 'king' or 'God,' indifferently. If his authority becomes widely recognized, if his empire includes subordinate kingdoms like that of the German Kaiser to-day, he becomes 'king of kings' and 'lord of lords.'

With the development of successive grades of honor, power and position comes the demand for recognition to be accorded by those below and the temptation to appease and flatter those above. The fundamental motive is the lively sense of favors to come; the wish to create obligation among those whose power enables them possibly to interfere with our welfare, and to exact allegiance from those whom we may possibly use for our own advantage. The ordinary father of a family addresses the king in the language of adulation, and is addressed in similar terms by his wives, children and servants; while these in turn receive from the dogs all the flattery that can be ostentatiously suggested by wagging tails and eloquent barking.

But while selfishness is one of the bases of title-giving, it is not the only one. Regard for others is a characteristic of humanity quite as natural and universal as self-regard. Selfishness and generosity are relative terms. The man or woman who is much less considerate of the rights of others than are the majority of people composing society is soon found out and becomes an object of dislike, if not of positive hatred. To be kind to one's friends, to take an interest in the welfare of those around us, to help those who are in trouble, to sympathize with the pleasures of those who are enjoying life, to make friends by being friendly—these are some of the most fertile sources of human happiness. Nor is this confined to humanity. If happiness can be judged by its visible manifestations, there is many a dog whose happiness is apparently bound up in the most unselfish devotion to his master. Love in the home circle and politeness in general society are not merely indications of refinement; they are positive contributions to the general

welfare of the race. Every one understands that social usage often suggests words, phrases and sentences which imply more or less covert flattery. Indulgence in them is not only pardonable, but often demanded by an unwritten law, even if they are not accordant with the severest requirements of truth. They give pleasure without really deceiving; they excite laughter without derision; they hide sorrow; they brighten life. Much title-giving has been the outcome of an unselfish desire to express appreciation and good will. It may not be wise, but it is a good-natured attempt to give pleasure by covert flattery.

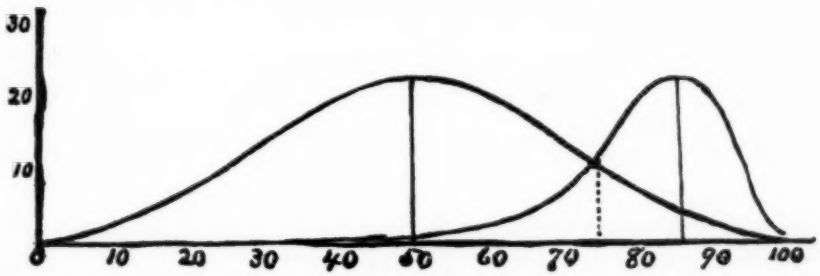
This unselfish basis for the giving of titles constitutes a sufficient explanation of that gradual diffusion and degradation of all distinctions that time invariably develops. A familiar example to all who have had experience in educational work is found in the class-room marking system, by which distinctions are based upon attainment in scholarship. Nearly a century ago the trustees of an academy well known in Virginia prescribed for the teachers a system of marking which was made up of three degrees of merit, *bonus, melior, optimus,* and three of demerit, *malus, pejor, pessimus.* If we apply to this the mathematical principle forming the basis of the theory of probabilities, it is easy to show that about 30 per cent. of all students examined ought to be graded *bonus,* and the same percentage *malus,* the sum of these two groups forming thus nearly two thirds of the whole. About 16 per cent. should be graded *melior* and the same percentage *pejor;* not quite 4 per cent. *optimus* and the same percentage *pessimus.* But what was the actual working of the system? The historian, Henry Ruffner, says: "The continual tendency was to mark inferior scholars too high. Thus it came to pass that not half the bad scholars got *malus,* the worst almost never fell below it, and *bonus,* though a mark of approbation, came to be considered as a disgrace, while *optimus* which ought to have been reserved for scholars of the highest merit, was commonly bestowed on all who rose above mediocrity." When Dr. Ruffner in 1829 became temporary president of the college into which this academy had developed, he secured the abolition of the discredited marking system, and the substitution of three grades: 'Disapproved,' 'Approved' and 'Distinguished.' According to the mathematical theory about 60 per cent. should have been approved, about 20 per cent. disapproved and 20 per cent. distinguished. But he writes that 'within two or three years some bad scholars were approved, and good scholars were nearly all distinguished.'

This continual temptation to grade as many as possible in the highest class is by no means based on selfishness alone, or even to any large extent on selfishness, though personal pride is one element. It is impossible for an examiner to make an exact numerical statement of

a mere judgment of merit. Since the estimate is confessedly only approximate, the student receives the benefit of every uncertainty. If any mistake has to be made, let him be encouraged by a false estimate that includes full credit rather than discouraged by one that does injustice. The numerical estimate of average success expressed as a percentage thus tends to become continually higher unless the generosity of the examiner is periodically and frequently checked by having his attention called to the absurdity of recording the majority of his students as distinguished. Dr. Ruffner says: "A temporizing professor who loves popularity, and desires, like the old man in the fable, to please everybody, is sure to be guilty of this fault, and, like many a politician, to sacrifice permanent good for temporary favor." If the passing mark is high, for example, 75 per cent., all marks will be proportionally high. What this limiting mark should be depends upon the idea underlying it. If the grade assigned means that the student is credited with knowing half, or three fourths, or nine tenths of what an ideally perfect student would know of the subject of study, the corresponding grade should obviously be 50, 75 or 90 per cent. Probably this is the most usual theoretic interpretation. But in practise the fundamental question is, in a large proportion of cases, not whether the student's attainments can be expressed accurately by a percentage, but merely whether in the teacher's judgment he ought to be passed or not. If so, his marks will be above the arbitrary limit, whatever may be the numerical value of this. If not, it makes little difference whether the grade assigned to the failure is 10, 30 or 50 per cent. In an institution where the teaching is good and where the discipline is firm and consistent, it is not often that more than one fourth of all students fail to pass in their studies. Theoretically, therefore, 25 per cent. would be better than 75 per cent. for the passing mark. This would mean no lowering of standard, but only a more rational system of marking than that which is most common. If results be represented graphically, the curve showing variation in grades attained would have its maximum corresponding to 50 per cent. This is an arithmetical mean between perfection and total failure, and should therefore be the numerical representation of the average grade. The curve would thus be substantially the symmetrical 'probability curve,' which is divided into two equal parts by the maximum ordinate, as shown in the accompanying diagram.

This study of the distribution of students' grades is worth more than passing notice, because it affords the best means of showing the tendency in relation to distinctions generally. Many years ago in a western university, by comparison of the grades of 287 students in physics, it was found that the average grade attained was about 85 per cent. In the institution with which the present writer is con-

nected, he made an investigation two years ago which showed that, taking into consideration all subjects of study available for the degree of bachelor of arts, the average grade of the average student under the average professor was 86 per cent., and that the most usual certificate conferred for successful work was a so-called 'certificate of distinction.' The curve of distribution is shown in contrast with the probability curve. According to this investigation it may be expected that about one student out of 200 or more will attain maximum grade. Out of 100 students about 10 may be expected to attain a grade of 95; 21



THE PROBABILITY CURVE HAS ITS MAXIMUM AT 50 PER CENT.; THAT OF DISTRIBUTION OF STUDENTS' GRADES AT 86 PER CENT. THE AXIS OF NUMBER OF STUDENTS IS VERTICAL; THAT OF PERCENTAGE GRADES IS HORIZONTAL.

will attain 90; 22 will attain 85. The slope of this unsymmetrical curve is thus very steep at the right. At the left of the maximum ordinate the slope is much more gentle, less than one twentieth of all grades assigned being below 60 per cent. In this connection it should be observed that the passing mark is 75. The area at the left of the dotted line corresponding to 75 is seen to be about one fifth of the whole area enclosed by the curve. This shows twenty per cent. of failures. Such a radical change of custom as that of substituting 20 or 25 for 75 as the passing mark, however desirable on account of its convenience and consistency, would be so misunderstood by both the students and the general public as to make a trial of the experiment very impolitic. The tendency to raise marks would at once re-assert itself, and very soon the majority of students would again be recorded with grades corresponding to the highest distinction.

This tendency to high marking is inherent in human nature. Every professor wishes to be at least as fair, at least as generous, as his conscience may permit; and he is apt to regard his own teaching at least as good as that of his colleagues. Every student wishes credit for the best he has done, and is at least willing to have his shortcomings excused. He considers the professor who gives him a high mark to be eminently fair; and the professor who remembers all shortcomings is thought to be unsympathetic and inconsiderate. To receive

a high mark is to receive a distinction, temporary perhaps, but none the less acceptable, and often stimulating, even if a high price has not been paid for it. All of us love to have others in sympathy with us, to receive expressions of esteem and to present testimonials of success. The supply becomes gradually adapted to the demand; and the demand causes all titles and distinctions to become more common, continually cheaper, until at last their meaning becomes merely nominal. To be nominally distinguished becomes the rule; to fail of such distinction becomes a disgrace.

In primitive society all government is the outcome of military organization. Aristocracy is originally based on brute force, and titles are the evidence of privilege accorded by the warrior chieftain in return for allegiance and military service. The assumption of a title without his consent is an act of rebellion and is treated as such by an absolute ruler. Limited monarchies have always been slow in development, and have in every case retained some features derived from the early establishment of caste fixed by privilege. The system of hereditary aristocracy which constitutes the groundwork of organization in English society is sustained by laws that could never have sprung originally from a democracy. Every Englishman knows his station. If he has not a place among the aristocracy by birth, he may still indulge the hope of admission to the charmed circle by royal favor. To call himself a lord, or to accept such a title by courtesy of his friends, or to buy it from some self-appointed college of heraldry would subject him at once to ridicule and social ostracism, even if he were not subject to prosecution for violation of long-established law. The mere fact of social organization imposes restraints upon personal liberty, but restraints that are deemed light in proportion to the general recognition of their reasonableness, justice and necessity. Personal liberty is, all in all, probably as nearly universal in England as it is in America, but the subjects in which limitation is imposed are somewhat different in the two countries. Titles and distinctions are granted in England in accordance with a well organized system, not theoretically perfect, but well enough established to be liable to but little misunderstanding. A colonel or a professor has no reason to fear ridicule in virtue of indiscriminate use of the title.

In America since the settlement at Jamestown there has been no basis for titles except the will of the more or less uninstructed people. Education was long exceedingly restricted. Aristocracy was based partly on personal character and partly on family influence, but never on legal prescription. There was no army requiring educated officers. A militia colonel was elected by his friends, and the title thus conferred by them was a possession for life. Throughout many parts of the south to-day by common consent a man is called colonel in virtue

of being a lawyer. No harm is intended by either the victim or the perpetrators of the practical joke. The explanation is perfectly simple, that by the inevitable process of good-natured degradation the words colonel and lawyer have in many places come to mean the same, neither of them suggesting the slightest suspicion of military education. In like manner, professors at first constituted a very limited class of scholarly men engaged in the work of college instruction, a class sharply differentiated from that of preparatory school teachers. This separation seems to have been maintained until the close of the civil war. But prior to the war the title had been assumed by dancing masters, showmen and all mountebanks. The good-natured American public, believing in universal freedom, had no objection to such thievery, and there was no law to prevent it. Annually the use of the title became more extended. Barbers, tailors, bootblacks and prize-fighters had as much right as the dancing master to assume any title that might have a commercial value. Teachers of high schools prepared students for advanced entrance in college. If the college teacher of geometry is called professor, why should not the distinction be extended to the high school teacher of the same subject? Moreover, what is the difference between a college and a high school? None whatever in many southern and western communities. If the high school teacher is a professor, why should a discrimination be made against the county superintendent, the grammar school principal, the primary school principal? The accommodating spirit of degradation has so changed the original signification of the word that now it may still mean a college teacher, but much more generally it means teacher without reference to the grade of teaching implied. Moreover, the great majority of teachers are persons with exceedingly small incomes; so that the title professor is in the large cities generally recognized as a badge of poverty.

Has the professor then no refuge from the charge of mediocrity implied in his once honored title? There is a Latin word for teacher, which was given a few centuries ago by the European universities to men who had proved their distinguished ability, such as Martin Luther or Nicholas Copernicus. The doctor was a man of learning, fit to teach medicine, or jurisprudence, or theology, or philosophy. Ambitious young men coveted the title, and the universities were places where doctors could lecture, and young men could enter upon the work of original investigation so as to establish their theses against all opponents. Even now the flood of literature made up of young doctors' theses in Germany is so great that no single reader can give attention to a tenth part of them. In America the university standards, in respect to both scholarship and scale of equipment, have risen so rapidly during the last few decades, that young doctors of all kinds are annually put forth by the hundred. The young man who is not a doctor

has now but little hope of winning the position of college teacher. The professor's refuge, therefore, is found in his doctorate.

But in this free country, made up of forty-five separate states with varying grades of civilization, each with its legislature able and willing to incorporate colleges with standards suited to local demands and local ideals, or absence of ideals, there is little hope of outgrowing the tendency to degradation of titles. If the dancing master was professor a third of a century ago, he is equally free in the early future to advertise himself as D.D., which for him means Doctor of Dancing. Our only hope is in the gradual elevation of educational standards, causing the people to become intolerant of such dishonesty. Titles received from universities should be protected by law in America as they are in Europe. The corrupt purchase and sale of professional degrees and of honorary degrees, which is now practised secretly, is to some extent punishable by law, but there is little vigilance in ferreting out offenders, and we seldom hear of prosecutions. Charlatanry will continue to be practised so long as there are gulls to be fooled in this world. Legislatures will continue to incorporate colleges without endowment, and these colleges will give degrees that imply no scholarship. With full knowledge that present evils will not be removed during the lifetime of any one now living, each educational institution that has a faculty of honest men can do its share toward the attainment of a higher moral standard of titles and distinctions by setting an example of truthfulness and moderation.

THE BIRD ROOKERIES ON THE ISLAND OF LAYSAN.*

By Professor C. C. NUTTING,
STATE UNIVERSITY OF IOWA.

PERHAPS the most interesting experience enjoyed by the naturalists of the U. S. S. *Albatross* during her recent Hawaiian cruise was a visit to Laysan, an island situated almost in mid Pacific, about eight hundred miles to the west and a little to the north of Honolulu.

As viewed from the anchorage, a more uninteresting bit of land could hardly be found, there being nothing in view save a stretch of coral sand beach surmounted by low bushes and relieved by a wooden light-house and the sheds of the guano company that leases the island. On the morning of our arrival the surf was the worst seen during the entire cruise. Nowhere did there appear to be a spot where the heavy swell did not break in thundering roars, and the rollers appeared to be at least twenty feet high. One of our party succeeded in making a landing in a small boat manned by Japanese, and thus secured a day with the camera ashore on the far-famed island of Laysan, and the experience was one not soon to be forgotten.

Fig. 1. Like Great Brown Goslings, balanced on their heels, with their toes in the air.

The road to the main albatross rookery is of the same white coral sand that covers almost the whole island. The glare is exceedingly trying to the eyes, and the heat would be oppressive to one who found time to think of it. Birds are everywhere, and so tame that they actually have to be shoved aside with the foot. The road was dotted with the young of the white albatross, with a sprinkling of adults. The youngsters were but three months old, although fully as large

* Published with the permission of Hon. George M. Bowers, U. S. Commissioner of Fish and Fisheries.

as the adults, covered with brownish down, except on the breast where the white permanent feathering had in most cases been acquired. Their appearance is ludicrous beyond description, reminding one of great brown goslings sitting upright, balanced on their heels with their toes in the air. Upon being approached they make no attempt whatever to escape, but straighten up as if about to give a military salute and snap their mandibles together with great rapidity, making a rattling noise amusing at first, but annoying after a few thousand repetitions. Occasionally they resented the intruding foot and vomited a quantity of half-digested food, a most disgusting mess, over the trouser leg of the visitor.

FIG. 2. ACRES AND ACRES OF LEVEL GROUND LITERALLY COVERED WITH ALBATROSSES.

The scene at the main rookery is beyond description. Here are acres and acres of level ground worn bare of vegetation and literally covered with albatrosses. At the time of our visit probably four out of five were young birds born the preceding February, although adults are everywhere sprinkled among them. Although the vast majority are of the white species, there are a few sooty albatrosses which generally prefer the upper levels of the beaches. Of course all these youngsters have to be fed, and at any given time most of the adults are at sea fishing for sustenance for their rapidly growing and voracious progeny. So far as we could ascertain this food consisted almost exclusively of *squid*. The stomachs we dissected contained squid and nothing else, and the only solid excrement was the eyes and beaks of these animals. Mr. Schlemmer, manager for the guano company, estimates that about two million albatrosses make their home

on Laysan, and one can well believe it. Although aggregated most densely at the rookery, these birds are everywhere on the island, which is

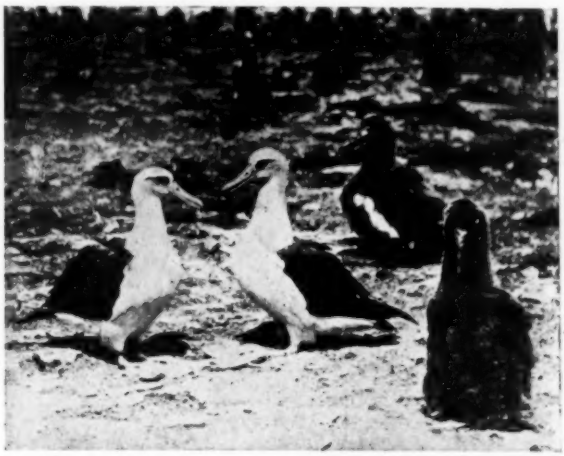


FIG. 3. ADULT BIRDS WERE EVERYWHERE SPRINKLED AMONG THEM.

in the shape of a rude quadrilateral about two by one and three fourths miles in area. Albatrosses are scattered everywhere, except on the tide-

FIG. 4. ABOUT TWO MILLION ALBATROSSES MAKE THEIR HOME ON LAYSAN. (From a photograph by Mr. Williams, of Honolulu.)

washed beaches and on the central lagoon. They are crouching under the shade of almost every bush and tuft of grass. The most conserva-

tive estimate of the necessary food supply yields almost incredible results. Cutting Mr. Schlemmer's estimate in two, there would be 1,000,000 birds, and allowing only half a pound a day for each, surely a minimum for these large, rapidly growing birds, they would consume no less than 250 tons daily.

FIG. 5. DOWNY YOUNG OF WHITE ALBATROSS.

The young birds do not appear to move about much, otherwise the parents would have difficulty in locating them when bringing food, and one can not but wonder how each finds its particular progeny among the hundreds of thousands that appear exactly alike to the human eye. Both parents assist in the labor of feeding the young, a most interesting process. When the parent alights near the young bird the latter begins to beg energetically by gesture, for they are silent as a rule, crouching before the old bird and working the head backward and forward in urgent appeal. Then the youngster grasps the bill of the adult, holding it crosswise, but at an acute angle, when the partly macerated food is squirted with unerring aim right down the throat of the feeding bird, apparently without the loss of a drop. This process is repeated again and again until the parent has literally pumped itself dry.

Here and there are small groups of adults engaged in a sort of play that may be a continuation of the courtship antics, a most laughable performance. The birds commence by walking around each other in a sort of 'cake-walk' with a peculiar swagger suggestive of the 'bowery boy' in his glory. Then they snap their mandibles together with amazing rapidity, making a rattling resembling the drumming of the woodpecker. Again they stand upright, facing each other, and put their bills under their wings 'as if hunting for a cigar,' as suggested by one of our officers. Next they stretch their necks upward with bills pointed

FIG. 6. SOOTY ALBATROSS FEEDING YOUNG.

heavenward, uttering a long-drawn 'ah-h-h-h-,' with a rising inflection. This play is repeated indefinitely, and with variations, and when, as

FIG. 7. HERE AND THERE ARE SMALL GROUPS OF ADULTS ENGAGED IN A SORT OF PLAY.

sometimes happens, it is accomplished in perfect unison, the effect is extremely laughable.

The life history of the albatrosses on Laysan, as given us by Mr. Schlemmer, is as follows: The eggs are laid late in January or early in

FIG. 8. THEY CIRCLE IN CLOUDS AROUND HIS HEAD.

February, both parents taking part in incubation. The nest is made by the female by merely scraping together the earth or mud wherever

she is resting and building it into an elevated ring within which her single egg is deposited. The young are hatched late in February,

FIG. 9. GROUP OF WIDE-AWAKE TERNS IN THE ROOKERY.

FIG. 10. THERE MUST BE MILLIONS OF WIDE-AWAKES NESTING AMONG THE BUSHES AND TUFTS OF GRASS.

usually, and both parents are kept busy from that time until fall in providing food for the little ones. By the latter part of September

the young have fully attained their adult plumage and are capable of sustained flight. Then the whole great host takes wing into the unknown. Literally so; for, so far as I can learn, this species, *Diomedea immutabilis* Roth, absolutely disappears from human ken for about two months of each year. There seems to be some evidence that it betakes itself to the Arctic seas. The apparent obliteration of this vast swarm of birds for a definite period annually is a mystery still to be solved. In November the birds arrive at Laysan as suddenly as they departed, and at once begin to prepare for domestic responsibilities. During the ten months annually spent there they do not appear to wander far from their breeding grounds. Indeed our vessel did not encounter them so far to the eastward as the main Hawaiian group.

FIG. 11. HOVERING WITH GRACEFUL POISE LIKE IMMENSE WHITE BUTTERFLIES.

Great as is the multitude of albatrosses and conspicuous as they are on account of their size, the terns of five or six species greatly exceed them in number, probably forming more than half of the entire bird population of the island. The clamor that greets the intruder in one of these immense tern rookeries is simply appalling, the air fairly quivering with their ear-splitting shrieks as they circle in clouds around his head and dash savagely directly at his face in their fierce endeavor to drive him away. There were probably hundreds of bushels of eggs of these birds at the time of our visit. The most numerous terns are the 'black-backed' and 'gray-backed' wideawakes, of which there must be millions, nesting among the bushes and tufts of grass, particularly on the southern end of the island. The vegetation grows right in the dazzling white coral sand, which appears as white as snow in the photographs.

FIG. 12. ROOKERY OF 'LOVE BIRDS.'

One of the most exquisitely beautiful birds that the writer has ever seen is a small tern known locally as the 'love bird,' pure white with large black eyes and bill. They have the habit of hovering with graceful poise over the intruder, like immense white butterflies, silently inspecting one as if impelled by a mild curiosity rather than resent-

ment, the actuating motive of the other terns. There are many small rookeries of these beautiful creatures scattered over the island; one in particular is in a very picturesque rocky nook at the south end.

FIG. 13. NODDY TERN ON NEST.

Two species of noddy terns are abundant, and much alike, except in size, being sooty brown with a grayish white cap.

FIG. 14. LARGE COLONIES OF MAN-O-WAR BIRDS WERE NESTING ON THE TOPS OF LOW BUSHES.

Large colonies of man-o-war birds were nesting on the tops of low bushes. These are among the most accomplished and graceful fliers

of all the avian world, and have the habit of soaring with extended wings for hours at a time. The males have an inflatable air-sack under the throat which can be distended at will into a great red pensile bag, resembling both in color and size the red toy balloons in which children delight. These birds are probably the most inveterate thieves and pirates of all the feathered tribe, robbing other birds of their fish, and even making them disgorge for the benefit of their persecutors. They lay a single white egg, and young in all stages of development were numerous. When the rookery was disturbed the incubating birds, both male and female, reluctantly left their eggs or young, in some instances carefully depositing a fish beside the young before leaving. Afterward, greatly to our surprise, they would swoop down, actually grazing our faces with their wings, and deftly seize a nestling by the head and make off with it, circling around high in air, finally dropping it to the ground, where it was eventually devoured. We could not

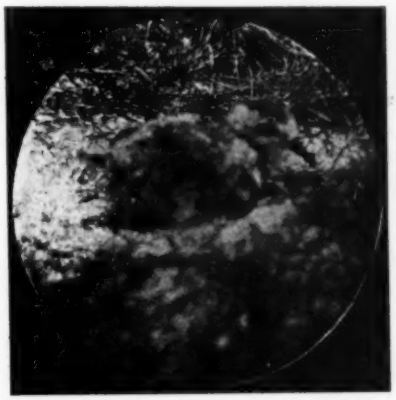


FIG. 15. YOUNG OF SHEARWATER SHOWING PROTECTIVE COLORATION.

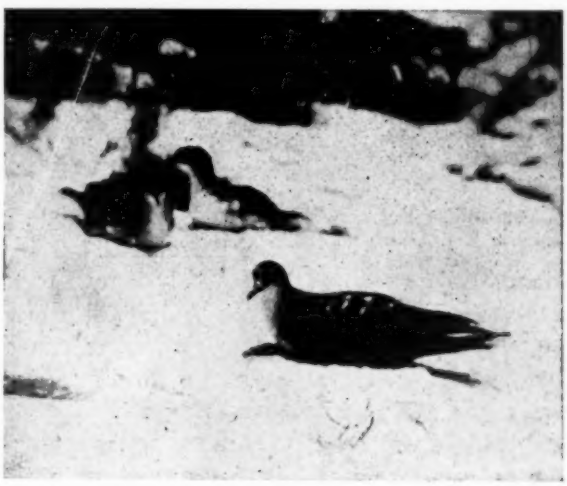


FIG. 16. SHEARWATERS NEAR BURROW.

determine whether the parents actually destroyed their own young or not, but it is probable that this revolting form of cannibalism must be added to the other crimes charged to their account.

FIG. 17. TROPIC BIRD ON NEST.

tenth' in a most undignified and precipitate manner, and is struggling waist deep in the yielding sand, an unwelcome invader of the home of the shearwater. This experience has the charm of novelty at first, but becomes exasperating after a score of repetitions in the course of an hour, with the perspiration streaming down one's face and the sand packed inside of one's shoes and clothing. How many scores or hundreds of thousands of these burrowing Procellaridæ there are on the island it is vain to estimate; but there are four or five species, and the entire surface is

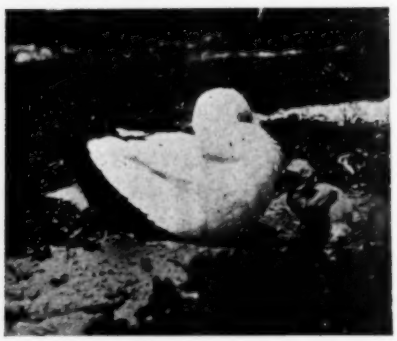


FIG. 19. 'SAND GANNET' WITH EGG AND YOUNG.

Not only does the bird fauna crowd all the available space on the ground, and in the bushes, and swarm in the air above, but still another vast multitude burrows under the sandy surface, forming a subterranean population that in itself would make the island of peculiar interest to the naturalist. Nor does the human visitor long remain in ignorance of this fact, for he has taken but a few steps anywhere among the bushes before he suddenly joins the 'submerged

FIG. 18. 'BUSH GANNET' ON NEST.

fairly undermined by their tunnels and burrowings. Their notes are melancholy beyond expression, being a distressful moaning, sometimes reminding one of the less romantic yowling of the night-wandering cat.

As one walks among the bushes he is from time to time greeted with most strident and piercing screams from nesting tropic birds, rarely beautiful creatures, pure satiny white, the wings and tail mainly black, the two central tail

feathers being excessively elongated and bright red. When nesting these birds are so well concealed that they would be unnoticed were it not for their strident outcries. This resulted in distressful experiences when the 'jackies' from the *Albatross* were given shore leave, and went around pulling the tail feathers from every tropic bird they could find; the birds refusing to leave the nests, but protesting vigorously and occasionally getting revenge by biting savagely with their powerful beaks.

The gannets are among the more conspicuous birds of the island, being large white birds with black wings. They are known as 'bush

FIG. 20. WINGLESS RAIL (below); LAYSAN FINCH (to the left); LAYSAN HONEYEATER (to the right). From a group mounted by Mr. R. M. Anderson.

gannet' and 'sand gannet,' names indicative of their nesting habits. The downy young of these birds are exquisitely white and fluffy, reminding one of animated puff balls.

The Laysan duck, curlews, plover and turn-stones are found in numbers along the margin of the central lagoon, and furnish a welcome addition to the larder of Mr. Schlemmer and the men in his employ. Four species of land birds complete the list. One is the 'wingless rail,' not literally wingless, but with wings reduced to functionless rudiments.

Another species confined to this limited area is the Laysan finch,

a large sparrow with yellow head and under surface and a rich sprightly song; and the last is the 'Laysan honey-eater,' a minute form with body and head rich, dark red, abundant among some shrubs with red blossoms growing near the lagoon.

Of course any estimate of the bird population of this remarkable island is little better than guess-work, but it seems safe to say that at least six or eight million make their home on this small atoll in mid Pacific, the total area of which, including the lagoon, is only about three and one half square miles. I know of no more dense population anywhere, although it may possibly be matched on some of the islands in the Alaskan region. But there a vast majority of the birds leave during the winter, while at Laysan nearly all remain at least ten months of the year.

Much of interest could be said concerning the guano deposits and the operations of the company that leases the island. Thousands of tons are exported annually, and it is entirely possible that this valuable fertilizer is now being deposited as rapidly as ever it was, owing to the wise policy of not disturbing the birds that is rigidly enforced by the company. The excrement is almost entirely fluid, and gradually saturates and fills the thin soil and porous coral rock, thus making the 'guano' of commerce. Strangely enough there is no very perceptible odor, even at the rookery.

The naturalists of the *Albatross* spent a week in studying the fauna and flora of this exceedingly interesting island, while the naval officers made a complete map, including a chart of the reefs near the anchorage. Here are found unexcelled conditions for collecting and studying the life histories of birds. All the species are very abundant, and can be seen in a day's visit. Every species can be caught, either in the hand or with a hand-net, and mercifully killed with chloroform without mutilation or blood-stains. They can all be studied at leisure, and at close range. The photographer finds himself in a veritable paradise, able to set up his camera at any desirable distance, even to 'pose' his subjects to suit his fancy, and take pictures of birds, nests and young to his heart's content.

It is simply delightful to find one spot, at least, in this world of ours where the birds are not afraid. So long as the guano holds out, these conditions will probably remain unchanged. If this time comes to an end, the government should see to it that this wonderful preserve of avian life is protected from the ravages of man, the destroyer, and of the rapidly diminishing moiety of his better half that still persists in the aboriginal feather-wearing habit.

BACTERIA IN MODERN ECONOMIC AGRICULTURE.

By ALBERT SCHNEIDER, M.D., PH.D.,
UNIVERSITY OF CALIFORNIA.

CROPS have been cultivated for thousands of years, and from the very first the agriculturist has endeavored to get from the soil a maximum return for a minimum of labor expended. Yet scientific progress in soil fertilization and crop improvement has been exceedingly slow until very recent years. Now scientific methods are beginning to be applied not only to crop and soil improvement, but also to the allied branches horticulture, arboriculture, the dairying industries, etc. That infant science, bacteriology, in particular, gives promise of inestimable value.

Some microorganisms work in the interests of the agriculturist, while others work decidedly antagonistically to all desirable interests. Much efficient work has been done in the eradication of disease-producing organisms, and the farmer is given detailed and specific instructions how to combat organisms which are hurtful to crops, as the rusts, smuts, rotting bacteria, etc. Attempts have been made to utilize even essentially harmful organisms in working useful results, as in the extermination of chintz bugs, potato beetles, plant lice; the extermination of rats, mice and other undesirable higher animals, by means of germs which are capable of transmitting fatal diseases to the animals referred to. The department of entomology at Washington has done some very effective work of this nature in exterminating insect pests of trees and plants.

The farmer's great future problem will be to determine what beneficial organisms may be pressed into his service and what noxious organisms may be suppressed, and how such measures may be carried out most expeditiously and with the best results. There is perhaps no problem of greater interest or none which gives promise of greater beneficial results than the one pertaining to the bacteria found in the root tubercles or nodules of leguminous plants (bean family). Without entering into the history of the discovery of these organisms or the part they play in the economy of the host plant, or even dwelling upon the many points still in dispute or under discussion, I shall describe briefly some of the recent attempts at making practical agricultural use of these organisms in Europe and in this country, and outline briefly a plan of future research, pointing out the additional practical possibilities which may be anticipated with reasonable certainty, based upon results already obtained.

It has been proved experimentally that not only do the bacteria (rhizobia) of leguminous root tubercles have the power of assimilating or chemically binding the free nitrogen of the air, but also other soil bacteria and various simple algæ and hyphal fungi. Undoubtedly the true ecological significance of these free nitrogen-assimilating functions of these organisms is to neutralize, balance or equalize the work of nitrifying and denitrifying (nitrogen-liberating) bacteria, which are very plentiful and widely distributed. More specifically considered, the organisms referred to chemically bind the free nitrogen of the air, forming nitrogenous compounds which may be taken up and assimilated by various plants. In the case of leguminous plants these nitrogen-assimilating bacteria (rhizobia) live within the roots (root tubercles) and supply the host directly with the enriching nitrogenous food compounds formed; in other instances the nitrogen-assimilating organisms live in the soil and the various higher plants as corn, wheat, etc., take up the compounds formed and deposited in the soil without being in actual biologic (symbiotic) association with them. These discoveries have suggested to the scientists interested in agriculture various possible improvements for increasing the yield of crops. Extensive and interesting experiments have already been made, and some noteworthy results have been obtained and, in other instances, investigations are under way which give promise of final useful results. Several processes for inoculating the soil or seeds with beneficial bacteria have been patented and, remarkable as it may seem, the slow, plodding German investigator is the first in the field with patent claims and 'practical' plans for utilizing bacteria in the interests of the farmer or the tiller of the soil.

The history of the discovery of the free-nitrogen-assimilating bacteria found in the root tubercles of leguminous plants is familiar to all botanists, but the general reader of science requires some detailed explanations and some specific statements regarding the subject in order that he may have reasonably clear ideas concerning the practical possibilities and probabilities of bacteria in modern agriculture. These necessary explanations will be given as we proceed.

The first to suggest a plan for practically utilizing root bacteria (rhizobia) and to secure letters patent for the process in Germany and in the United States were Nobbe and Hiltner, of Tharand, Germany. Since the wording of the specifications for a patent are required to be simple and intelligible to persons of ordinary technical learning, the scheme can best be presented by simply quoting the specifications. The following is the specification which forms part of letters patent No. 570,873 granted Nobbe and Hiltner in the United States, November 3, 1896:

Be it known that we, Friedrich Nobbe and Lorenz Hiltner, of Tharand, pared for transport in fluid cultures. The colonies in the agar-gelatin are disinoculation of soil for the cultivation of leguminous plants and we do hereby declare the following to be a clear and exact description of the invention:

Since the function of the root nodules or tubercles of the Leguminosæ in the supply of nitrogen to these plants has been discovered by the fundamental researches of Hellriegel we have been working on this problem for a number of years, and have examined more especially the bacteria in said nodules or tubercles (first identified and isolated in cultures by Beyerinck) in order to determine the relationship between the bacteria and the reception of the free uncombined nitrogen of the air in the soil by the various kinds of Leguminosæ. These researches have resulted, in the first place, in the confirmation of the at that time still disputed fact that the introduction of these bacteria into the soil produces, without exception, in soil free from these bacteria, the root nodules or tubercles on the plants in question having papilionaceous flowers and enables these plants to assimilate the free nitrogen. A soil inoculated with these bacteria, even when it contains absolutely no nitrogen in an assimilable form so that the plants without any such inoculation would starve, enables the Leguminosæ to produce as rich a yield of dry material and nitrogen as they would otherwise produce if grown in a richly manured soil containing much assimilable nitrogen.

It has been established by us as an entirely new fact that the tubercle bacteria of the various Papilionaceæ are of full strength (*i. e.*, in the production of efficient nodules or tubercles) only in that species (of leguminous plant) from whose root tubercles they were themselves obtained. With closely allied species they are of less strength and with systematically different species they are useless or inactive. Bacteria cultures from pea roots, for example, are quite useless for *Robinia* plants, while they promote the growth of peas in a very energetic manner, and that of the allied vetches somewhat more feebly; on the other hand, the bacteria from *Robinia* nodules or tubercles are quite efficient with *Robinia* plants, but in a lesser degree with *Colutea*, and are absolutely useless with peas.

At first sight it might possibly be thought that the production, transport, and distribution of such large masses of crude inoculating material as would appear to be necessary for the sufficient impregnation or treatment of large areas of land would be very difficult and costly, and therefore not practicable, while there would also be the danger that in the crude inoculating material, besides the active bacteria of the root nodules or tubercles, there would be carried from field to field, at the same time, microscopic organisms which would be detrimental to growth and would interfere more or less with the action of the inoculating material. Our process is, however, free from any such objections as those above mentioned, inasmuch as bacteria bred in quantities directly from the nodules or tubercles of the Leguminosæ in pure cultures are used as the inoculating material. Farmers are, therefore, placed in a position to make land, which was unfruitful by reason of its lack of nitrogen, fit for the cultivation of fodder and other plants belonging to the order of the Leguminosæ and to insure and increase the yield of soil. This inoculation has, moreover, an essential practical bearing in connection with the so-called 'green manuring.'

Our process of inoculating land with tubercle bacteria is to be carried out as follows: The active bacteria to promote the growth of the Leguminosæ are delivered to the farmer in glass tubes or other suitable packages, which contain pure colonies thereof in agar-gelatin having suitable additions for propagating such bacteria, for instance sugar, asparagin and an aqueous extract of the green

substance of the Leguminosæ. In some cases the bacteria can also be prepared for transport in fluid cultures. The colonies in the agar-gelatin are distributed in water, together with the agar-gelatin, by the user (after removing the stopper) in the proportion, for example, of the contents of one glass tube to from one to three liters of water, which is previously mixed with a suitable material, such as an aqueous extract of the green substance of Leguminosæ sugar asparagin, for propagating the bacteria. This propagating material is delivered with the bacteria tubes. Preferably the glass tube is laid in the water until the agar-gelatine is dissolved.

Immediately before sowing, the whole of the emulsion prepared as above mentioned is poured over the seeds. The amount of water added for each kind of seed is so proportioned that after the seeds have been thoroughly and uniformly moistened by a careful working over by hand, a surplus of liquid will still remain. For clover-seed, for example, for twenty kilograms of seed the admixture of three liters of water with the contents of three glasses of inoculating material (each glass containing, for instance, three cubic centimeters agar-gelatin with pure cultures) is sufficient. For more bulky seeds a somewhat larger amount of water is required. A sufficient quantity of dry sand or earth from the field to be sown is then gradually added with careful stirring, until the body of seed is in a suitable condition for sowing by hand or by means of a sowing machine.

This microbic (rhizobic) soil fertilizer for leguminous plants was given the commercial name 'nitragin,' and its efficiency was quite carefully and extensively tested and commented upon by European and American investigators. The consensus of opinion seemed to be that it was of doubtful practical utility for agricultural purposes. Some authorities maintained that it was of unquestionable value in virgin soil. In rich and otherwise favorable soil conditions it is of only slight value. It is maintained that nitragin aids very materially in developing and ripening the fruit. As becomes evident from careful consideration, the value of this microbic fertilizer depends upon whether it will cause an increased development in the number and size of root tubercles over and above those which would develop without the presence of this artificial aid. If the soil is already well supplied with rhizobia or root tubercle bacteria, as soil naturally would be if the leguminous plants under consideration had been grown in it for one or more seasons, nitragin would in all probability be of little or no value. In any case the anticipated practical results have not been realized, as I am informed by a letter from Victor Koechl & Co. of New York City which states that 'nitragin is withdrawn from the market and is no longer manufactured.'

A second and later improvement in the method of inoculating seeds with root tubercle bacteria (rhizobia) is given by Hartleb in the following specifications forming part of letters patent No. 674,765, granted May 21, 1901, at Washington, D. C.:

Be it known that I, Richard Hartleb, a citizen of Germany, residing at the Botanisches Institute der Hochschule, Aachen, in the Empire of Germany, have

invented a certain new and useful method of inoculating seeds with microorganisms, (for which I have applied for a patent in Germany, dated February 23, 1900) of which the following is a specification:

This invention relates to a method of inoculating seeds with microorganisms. For this purpose the seeds in a suitable container are covered with pure water, so that they are mechanically cleaned, and the damaged or dead seeds float to the surface of the water. The water and the impurities are then poured off and the cleaned seeds are left in the water until they begin to swell. whereupon there is a loosening of the external husk of the seed and an increase in the volume of the grain, so that the seed offers an increased surface for the microorganisms and the latter obtain easy access, owing to the loosening of the husk. The seed thus prepared is sown directly without admixture of any other substance.

The application of this method is to the inoculation of seeds with bakteroids of the microorganisms of the Leguminosæ. Very shortly after the seed has become imbedded in the soil nodule (root tubercle) formation begins. The danger of killing the organisms for the inoculation by harmful soil influences is effectively obviated, owing to the fact that these organisms in consequence of the rapid germination quickly become active. On the other hand, this danger of damage or death is always present in a seed which has been merely inoculated with the liquid and has not been allowed to swell therein, so that it is a long time in germinating.

Although not specifically stated in the above specification, it is evident that the Hartleb process is a method of applying pure rhizobia cultures to seeds of leguminous plants only. Whether the method offers any advantages over the method of Nobbe and Hiltner is questionable. In any case it would prove practically advantageous only under the conditions referred to under the discussion of nitragin. Although the method has been freely discussed and experimented upon in Germany, I am not aware that the fertilizer is on the market, certainly not in the United States.

There is on the market a third patented germ or microbic soil fertilizer of German origin known as 'alinit.' It consists essentially of a pure culture of the soil bacillus known as *Bacillus Ellenbachiensis alpha* or *Bacillus Ellenbachiensis* Caron. The germ was first brought to the attention of agriculturists by Caron, a land owner of Germany, who first isolated it and called attention to the fact that it had the power of chemically binding the free nitrogen of the air. The microbe is undoubtedly closely related to *B. megatherium* and perhaps also to *B. anthracis*. According to some authorities it is especially concerned in assimilating free nitrogen for gramineous plants (grass family; *Gramineæ*). If this is true it may prove of great value to grain growers.

The commercial alinit is a dry pulverulent substance of a yellowish gray color, with about 10 per cent. moisture and 2.5 per cent. nitrogen. It is evidently prepared by mixing spore-bearing pure cultures of the bacillus of Caron with a base of starch and albumen. It

is used to inoculate soil either by spreading it broadcast or by sowing or otherwise planting it with the seeds. It is not a nodule or root tubercle-forming organism and does not enter into intimate symbiotic or biologic relationship with plants. Its work is simply that of binding free nitrogen, forming nitrogenous compounds which enrich the soil, thus increasing the yield of any crop benefited by such compounds. Whether alinit binds free nitrogen more actively in the presence of gramineous plants must be more accurately determined by experiment.

In 1892, through a suggestion by Professor Conway MacMillan, state botanist of Minnesota, the writer conceived the idea of modifying leguminous tubercle bacteria by special culture methods so as to induce them to develop in or upon the roots of gramineous plants, as corn, wheat, oats, rye, and barley. Investigations in this direction were begun at the Illinois Experiment Station at Champaign in 1893, under the direction of Dr. T. J. Burrill. The time granted for experimenting was much too brief for obtaining any definite results. At that time comparatively little was known of nodule bacteria (rhizobia) in artificial culture media and most of the time allotted was consumed in making cultures or attempting to make cultures of the rhizobia of different species of leguminous plants. No field experiments were attempted, but some laboratory observations were made by inoculating sprouting corn grown in vessels filled with sterile sandy soil with pure cultures of rhizobia grown upon corn extract agar media, the supposition being that the corn extract would produce the desirable changes in the organisms. After a few weeks the roots of the young inoculated corn plants were examined microscopically to determine if the presumably modified microbes showed any tendency to develop in or on the root cells. In some instances numerous microbes were found in the hair cells (trichomes) of terminal rootlets and in epidermal cells and cells in apical areas, particularly at the points of secondary root formation. While it was not experimentally proved that the microbes present were rhizobia, it is highly probable that they were, as the examination of control plants not inoculated, also grown in sterile sandy soil, showed the absence of germs in root tissues and root trichomes. It was apparent that the inoculated corn plants were thriftier and of a deeper green than the control plants or those not inoculated. Though the results are meager and far from conclusive, yet the experiments pointed toward final, more positive results. The experiment station research was now terminated, and other work kept the writer from again taking up this line of research extensively until early in 1902. At this time the investigations were begun in the bacteriological laboratory of the Northwestern University School of Pharmacy at Chicago. Pure cultures of the rhizobia of white clover

(*Melilotus alba*) were grown upon corn extract with agar. Again considerable difficulty was encountered because of lack of information regarding the behavior of this particular variety or species of rhizobium in artificial culture media. It was not until the early part of July that definite and satisfactory conclusions were reached regarding the identity of this organism in the culture media indicated. The rhizobia were now transferred to fresh corn extract media from time to time for about six weeks; in order to effect the desired adaptive changes in the microbes. Some preliminary field experiments were carried on at a farm near Fairbury, Illinois. Plots of stubble ground were selected in which oats had been grown during the season. The ground was ploughed and harrowed repeatedly. Each plot of ground was duplicated for control purposes. On August 10 the plots were planted with white dent corn mixed with the rhizobia cultures and a small quantity of water. The seeds germinated uniformly with no appreciable differences in the various plots. Subsequent growth was carefully observed for a period of four weeks. No very marked difference was noticeable. The corn treated with rhizobia grown in neutral corn-extract agar seemed to thrive somewhat better than the rest, but the difference was not sufficiently marked to be noteworthy. The corn treated with acid agar corn-extract rhizobia showed no apparent improvement over the normal or untreated corn. The same could be said of the corn treated with crushed nodules of sweet clover. Opportunity did not present itself for making a comparative microscopic examination of the roots of the corn of the various plots. Oats was also experimented upon, but with no marked results. This in brief is the outline of the experiments of 1902 and, although no satisfactory results were obtained, the preponderance of experimental evidences again seemed to point to ultimate success. In fact so sanguine had the writer become of early marked success that he made application for letters patent for the process, but the application in the form in which it was presented was rejected on the patents by Nobbe and Hiltner and by Hartleb. The specifications filed September 29, 1902, read in part as follows:

> The invention relates to the process of fertilizing the soil and increasing the yield of crops by means of specially modified pure cultures of the microbes or organisms found in the soil and in the root nodules or tubercles of plants belonging to the leguminosæ or bean family, and has for its object to render the process more effective, much cheaper and practically without the expenditure of additional labor.
>
> The living microbic fertilizer, consisting of the above mentioned modified organisms is applied by simply mixing a small quantity of the culture with the seeds just prior to planting, and introducing it into the soil simultaneously with the seed. With the germination of the seed thus treated, the modified microbes will also begin to multiply and appropriate for the use of the plant, the free nitrogen of the air.

In spite of the wonderful opportunities for the dissemination of learning, the exchange of scientific thought and plans of research and the efficient modern laboratory equipment, scientific progress is slow. To illustrate, the observations and experiments which led to the discovery of the root nodule bacteria were begun about 1862 by Hellriegel in Germany and Lawes and Gilbert in England. The nodule microbe was not discovered or recognized until 1886. At the present time we are just beginning to become scientifically familiar with the microbe and are undertaking experiments with a view to practical useful application of this microbe. In consideration of these facts it need not appear surprising that conclusive results should not, at the time, have been obtained in the line of research indicated. It is of course understood that any scientific research deserving of the name must be founded upon reasonable and sound principles. The entire experimental plan must be in harmony with the highest and best results already obtained. The following are the essential and important points for consideration and upon which the research work indicated is to be based:

1. Do rhizobia (nodule bacteria of leguminous plants) assimilate free nitrogen in artificial culture media or when not symbiotically associated with leguminous plants? Based upon the results of extensive research work, in particular by German investigators, this question is to be answered in the affirmative. A negative result would mean that it would in all probability be wholly impossible to obtain the anticipated outcome of the experiments. Since this question is, however, to be answered in the affirmative, the next question in importance is

2. Can rhizobia of leguminous plants be so modified by special culture methods as to induce them to develop in and upon the roots of other plants, as corn, wheat, rye, barley, etc.? Although, as already indicated, the experimental results thus far obtained are not conclusive, yet the *indications* are that they will finally prove successful. German investigators have shown that one variety of leguminous rhizobium may, by culture methods, be converted into another variety. That is, for example, the rhizobium of the bean nodules may be induced to develop nodules on the roots of the pea, and perhaps other species of closely related genera. This is, in part, denied by Nobbe and Hiltner in the specifications of patent claim, as above recorded. It is, however, generally admitted by investigators that the rhizobia of the majority of leguminous plants are morphologically very variable, and undergo very marked structural changes in different culture media and within the host root nodules at different periods of the season and of growth. Such pronounced polymorphism coincides with marked adaptive changes to new or changed environment, and it is, there-

fore, highly probable that these polymorphic rhizobia may be induced to change hosts, at least temporarily, which is really all that is required for the success of the experiments. That is, it is desired that the rhizobia should live and multiply in or upon the roots of gramineous plants during one season or from the time of seed germination to the ripening of the crop (in annuals). This question is intimately associated with the following:

3. Even should it be possible to induce the rhizobia to develop in and upon roots of gramineous (and other non-leguminous) plants, would they still retain the power of assimilating free nitrogen? It is highly probable that this question can be answered in the affirmative, although Lafar makes the statement that the rhizobia in certain stages of existence, for instance those which exist in the infecting threads (Infectionsfäden) of nodules and predominate in young tubercles and in the apical areas of all tubercles, exist in a purely parasitic or harmful relationship with the host plant. It is, however, highly probable that this statement is not founded upon experimental proof. The assimilation of free nitrogen is an essential function of rhizobia, and it is certainly reasonable to assume that the function would continue, though perhaps in a modified degree, no matter how marked the morphological adaptive changes might be. This question can be settled very simply and easily as the experiments progress.

The following question should also be carefully considered:

4. Are there soil bacteria or other organisms, not found in leguminous root nodules, which assimilate free nitrogen and which may be especially adapted to gramineous plants? From what has already been stated, it would appear that the *Bacillus Ellenbachiensis* of Caron is such an organism. If it should become evident that this organism assimilates free nitrogen principally in association with gramineous plants, it would seem to give promise of great utility in the more effective cultivation of gramineous plants. This organism would be especially advantageous, because, in contradistinction to rhizobia, it forms spores. Spore-bearing cultures would be desirable, because they would keep better and longer. The microbic fertilizer could be put up in dried form and sent to farmers at great distances without danger of becoming worthless. It could be kept for months, or perhaps even a year or more, though this in itself would not be of prime advantage. Further extensive researches would be necessary to determine to what extent adaptive changes could be developed in this particular microbe.

Finally the question will arise,

5. In what morphological, biological and bio-chemical relationship would the modified organisms establish themselves with the prospective or new host plant? It is, of course, not to be anticipated that they would cause the development of root nodules or tubercles or cause

any considerable morphological change in root tissues. Nor is it at all highly probable that the anticipated morphological and biological adaptive relationship would be permanent or auto-transmissible to other generations of the new host. It is probable that the relationship would be temporary only. It may be quite marked at the period of seed germination and then gradually decline more or less rapidly.

The time required to change or modify the rhizobia sufficiently to induce them to develop in or upon the roots of gramineous and other non-leguminous plants must be determined experimentally, and this is the most essential part of the experimentation. It is reasonable to assume that considerable time will be required, one year, and perhaps even a much longer period. It will also be necessary to experiment with various media in order to determine which particular culture medium will produce the desired changes most effectively and most rapidly. Present indications are that acid media are not specially indicated as was once supposed, though they induce rapid and very marked morphological changes in the rhizobia.

The agricultural conditions of Europe are quite different from those of the United States. In the plan of research suggested, the interests of the American farmer are of prime importance. Wheat and corn are the two staple farm products of the central, eastern and western states, and in the above discussion these have been primarily in mind. Later researches may be extended to other American farm products, as cotton, tobacco, potatoes, etc. Opportunity must be had to make frequent field experiments or tests along with the purely laboratory experimentation.

The successful outcome of the research will result in inestimable value to farmers. The modified microbic soil fertilizer will serve essentially as a living fertilizer; it will do away with the use of the well-known guano, manure and other chemical fertilizers, which are applied at great labor and expense. It will also do away with the need of crop rotation, which to the agriculturist is a costly process, as it necessarily reduces the cultivation of the staple farm product. It is hoped that the increase in crop yield, resulting from the use of the microbic soil fertilizer, will amount to from 5 per cent. to even 50 per cent., depending primarily upon the condition of the soil. Rich soil naturally requires no fertilizer of any kind.

The following is a brief summary of the essential points discussed in this paper with special reference to the plan of research outline:

1. Bacteria of the root nodules of leguminous plants (rhizobia) have the power of assimilating free nitrogen independent of their intimate biologic association with the host plant.

2. Rhizobia, especially the species known as *R. mutabile,* found in the root nodules of the majority of leguminous plants, are highly poly-

morphic and readily undergo marked morphological changes in different culture media and under varying environmental conditions.

3. The species or variety of rhizobium living in natural symbiotic or biologic relationship with one given species of leguminous plant may be so modified artificially as to induce it to live in a similar relationship with a different species of leguminous plant, indicating great biologic adaptability.

4. It is probable that rhizobia of various leguminous plants may be so modified by special culture methods as to induce them to develop in or upon the roots of non-leguminous plants, continuing their free nitrogen-assimilating function, thus supplying such plants with nitrogenous compounds which serve as soil fertilizer or food for the plants with which the modified rhizobia will form a temporary intimate relationship.

5. The bacillus of Caron (*Bacillus Ellenbachiensis*) also gives promise of great utility in future economic agriculture, especially in the cultivation of gramineous plants.

THE STORY OF ENGLISH EDUCATION. II.

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IT is not possible in the space allotted to such an article as this to deal in any detail with the mass of facts that fill the seventy years that have passed since this first government grant in aid of education. It is possible, however, to indicate the course of events. Previous to 1870, apart from unsatisfactory and more or less ineffective factory acts, and apart from revenue statutes providing yearly grants, there was no legislation. Educational work was undertaken for the most part by the education committee of the Privy Council, formed in 1839, and the great school societies. From 1833 to 1839 the annual grant of £20,000 was administered by the treasury through these societies. In 1839 Queen Victoria, on the occasion of the creation of the committee of council on education, expressed through Lord John Russell the wish 'that the youth of this kingdom should be religiously brought up, and that the rights of conscience should be respected.' Some statistics of a comparative character may here be noted with advantage. The population of England and Wales in 1833 was almost 14,000,000, and the number of day scholars of all classes nearly 1,300,000, a number that was about nine per cent. of the population. If one in every eleven of the population was at school, it did not prove that the working classes were in so favorable a case. In fact we may take it that under one million scholars belonged to the working class; in other words that not one in fourteen of the laboring population was at school, when in fact, one in six ought to have been at school. Thus a great many more than half of the children had no education at all. By the year 1851 matters had somewhat improved. The population was then about 18,000,000, and of this population some 1,600,000 of the children of the laboring poor were at school. In other words, about one in ten instead of one in six of the poorer part of the population were at school in 1851. At this date almost exactly half the children had no education at all. By the year 1870 the population had reached 22,000,000, of whom 19,000,000 constituted the manual-work class. About 1,700,000 children belonging to this class were at school, or say, one in eleven of the population. This looks like a decline on the position in 1851. This is, however, extremely improbable, and it is more likely that the available figures for 1851 are in error. The improvement between 1851 and 1870 was most marked in the methods of education employed and in the books used. The school-teaching was practically valueless in 1833, it was not of great value in 1851, and

in 1870 it was only beginning (despite the great advance on 1851) to be of real value. In 1870, out of every 1,000 children qualified by age and attendance for the examination in the two higher standards, 319 ought to have been prepared to pass. In fact only 98 were presented for the examination. Slow as was the progress between 1833 and 1870, ceaseless efforts had been made to hasten that progress. Population and the congestion of soul-ruining unsanitary areas, however, progressed more rapidly than the education movement and 1870 found a million and a half of little children without the means of education. Yet philanthropists and statesmen had striven manfully enough to solve the awful problem. A select committee of the House of Commons in 1838 reported on the deplorable conditions of education in the great towns. This led to the institution of the education committee of the Privy Council. The inquiry made by the National Society in 1846–7 showed that the established church was striving with might and main to do its duty, for it was actually educating one million children in its day schools. A select committee of the House of Commons in 1852 reported on the Manchester district of England and showed a school attendance improvement of no less than 300 per cent. The Duke of Newcastle's commission appointed in 1858 recommended, after a lengthy examination of the education problem, grants out of rates as well as out of the imperial exchequer, advised the creation of local boards of education in every county area, advocated a more efficient system for the training of teachers, and an extension of evening schools. The grants out of the rates were to be paid in respect of individual scholars upon examination by examiners appointed by the local boards of education. The revised code introduced by Mr. Lowe—the code governing the conditions under which the education committee of the Privy Council made the grants to the schools—adopted the principle of individual examination and the payment of all grants direct to the managers of the schools that earned the grant. Mr. Lowe in a famous phrase promised that the system should be either cheap or efficient. When he made this promise it was dear and inefficient. Under the revised code the parliamentary annual grant fell from £813,441 in 1861 to £636,810 in 1865. The system, however, was not efficient and it was found necessary once more to strive after educational legislation. In 1843 an effort had been made to pass a factory act that would secure some measure of religious and useful education to all children in the factories. The bill, however, in consequence of nonconformist opposition, was withdrawn. In 1853 a bill was introduced enabling those borough councils that chose to adopt the act to appoint a school committee for the purpose of controlling the elementary education of the district. It was proposed in this measure that any elementary school should be admitted to this control and reap its manifold benefits on the application of the school

managers for such admission. Admitted schools were to be inspected. Expenditure under the act was to be met out of the borough fund to the extent of sixpence on the pound. The bill was coldly received and withdrawn. About the same time were introduced education bills emanating from Manchester school societies. One advocated free secular rate-paid education; the other the assistance out of the rates of denominational schools. These two bills were referred to a select committee of the House of Commons on February 17, 1853. The bills were eventually dropped. In 1855 the denominational bill with a provision for the foundation of new schools was re-introduced by Sir John Pakington. In the same session Lord John Russell introduced another borough bill, with a full conscience clause; while the free schools bill again represented the views of the Manchester secular party. The three bills were all abandoned. Bills were once more, without effect, introduced by Lord John Russell in 1856 and Sir John Pakington in 1857. These were followed by the comparative unsuccess of Mr. Robert Lowe's revised code. In 1867 came the beginning of the end, or rather of the beginning. What was practically the Manchester denominational schools bill was introduced by Mr. Bruce, Mr. W. E. Forster and Mr. Algernon Egerton. It was a carefully prepared scheme, but unfortunately it was not compulsory in form. Each locality could adopt or refuse it. In the then state of education the worst districts would have refused to adopt the act. The bill was withdrawn, and in 1868 the Duke of Marlborough introduced into the House of Lords a bill that purported to solve the problem without the aid of rates. The bill merely proposed to put a modification of Mr. Lowe's administrative code into an act of Parliament. Such a bill could but fail. In the same year the bill of 1867 was again introduced, and on this occasion it offered the compulsory system. The feeling that this bill would involve compulsory rate-aid for denominational schools under private management, and the fact that it gave the proposed board of education power to enforce the act in any district exhibiting educational destitution, contrary to the will of the district, weighed against the bill and it was withdrawn on June 24, 1868. The final step came when the bill of 1870 was introduced on February 17. It received the Royal consent on August 9, 1870.

The education act of 1870 divided England into school districts for the purposes of elementary education, and enacted that in every district a sufficient amount of accommodation must be provided in public elementary schools for all children resident in the district, for whose elementary education sufficient and suitable provision was not otherwise made. The meaning of 'elementary education' was not defined by the act, but in the famous *Cockerton case,* decided in 1901, it was settled that the phrase was an elastic term 'which may shift with the growth of general instruction and

attainment.' The schools were bound by a conscience clause and had to be open to government inspectors, who could report whether the conditions laid down by the central authority as precedent to a grant had been complied with. This new system comprised two kinds of schools—the schools supported by voluntary subscriptions, which were in existence at the date of the passing of the act, and board schools. These latter schools came into existence in districts where there was insufficient voluntary school accommodation and where in consequence the rate payers had elected a school board. This board erected, at the expense of the rate payers, schools sufficient to supply the wants of the district, and these schools were maintained out of the rates, central grants and school fees. In the board schools, in addition to the conscience clause in use in voluntary schools, the Cowper-Temple clause of the act of 1870 enforced the rule that 'no religious catechism or religious formulary which is distinctive of any particular denomination shall be taught in the school.' Thus the effect of the act of 1870 was to place side by side two great school systems—a denominational system, the schools of which had for the most part been built and were maintained by voluntary subscriptions, to some extent supplemented by grants—and an undenominational rate-supported system independent of voluntary subscriptions. The passage of years saw the rapid increase and development of both systems. The act of 1870 gave the various school boards power to compel parents by by-laws to send children to school between the ages of five and thirteen years, but it was not until 1876 that the legislature created the universal parental duty of causing all children to 'receive sufficient elementary instruction in reading, writing and arithmetic.' This was followed in 1891 by an act granting to practically all the public elementary schools a fee-grant in lieu of the fees hitherto paid by the parents. This important step of creating free elementary education was an almost necessary corollary of the institution of compulsory education, and it was essential for the reason that those children who most needed school life were the offspring of the most needy parents. The result of these various acts was to create vast school board systems in London and the great towns which in certain areas crushed the voluntary schools out of existence. The standard imposed by the Education Department rapidly rose, and the number of subjects taught greatly increased. Gradually the great school boards endeavored, by the creation of what were known as higher elementary schools, to bring secondary education within their control and to supply this education out of the rates in competition with the newly-efficient endowed secondary schools of their districts. In 1901, in the famous case of *Cockerton,* it was held that this was illegal, and it became necessary at once to create by statute a national system that should control and develop both primary and secondary education. The school board system, while it had been

successful in imparting in the great towns a considerable measure of elementary education to the mass of the poorer children, had had a bad influence in lowering the standard of secondary education by compelling the strictly secondary schools to come down to the standard of the higher elementary schools. Higher elementary education at its best gave the child some smattering of culture but it ended there and was in no sense a step in the ladder of education. In the rural and urban districts, moreover, the voluntary schools had more than held their own. The board schools of these districts were often badly managed and were less efficient in many cases than the voluntary denominational schools, which, despite financial difficulties, increased in number and efficiency. The fine work done by these schools was considered to justify in 1897 the creation of a special aid-grant to voluntary schools. But even with such help the position of the voluntary system had become precarious. The high standard of elementary education, of accommodation and of teachers imposed by the Board of Education could only with great difficulty be attained with the means at the disposal of the managers of voluntary schools. The subscribers increased their subscriptions, but since as rate payers these subscribers had frequently also to pay a school board for schools competing with their own schools, it was plain that the limit of subscriptions had been nearly reached. It was clearly inequitable that a person should pay to support both a voluntary and a compulsory system, and it was also evident that both systems suffered in efficiency in consequence.

The time, therefore, had been reached when all forms of education required coordination and increased state help. The absence of continuity between the various grades and kinds of education had, by the year 1902, become a serious national danger. I have noticed already some aspects of this discontinuity. It is necessary here to refer to certain other sides of the question. For nearly fifty years the Science and Art Department of South Kensington had distributed under the direction of the Education Department—now the Board of Education—to schools of all kinds a large parliamentary grant in aid of an elaborate scheme of education set forth by the South Kensington officials. The school boards for a considerable period used the rates, quite illegally, for the purpose of teaching science and art in accordance with the South Kensington scheme in order to earn the grants. This scheme provided the elementary schools with a kind of secondary system and thus increased an undesirable competition with the endowed secondary schools. On the other hand these true secondary schools from the year 1890 have received in many instances parliamentary help of another character. By an act of that year the residue of certain customs and excise duties—a very large annual sum*—was directed to be dis-

* Say £1,200,000. The Science and Art grants and these duties amount to more than £1,500,000, so that it can hardly be said that secondary education has, since 1890, been neglected in England.

tributed to the County Councils throughout the country for the purpose of encouraging technical education. This money was and is awarded to the secondary schools by way of grants in recognition of successful results achieved by the school in technical education. These grants have proved so necessary to the various secondary schools that such schools have been compelled to start an efficient system of technical education in order to earn them. In this respect competition with the primary schools has done good. It has forced the secondary schools to find a new source of income beyond endowment and fees and has thus brought the ancient secondary or grammar school system of England into relationship with the state. The state has not been slow to recognize the relationship. In addition to the technical education grants it now makes special grants to all secondary schools that are prepared to attain a certain standard of efficiency in certain subjects—scientific and literary—named by the Board of Education. It is not, however, difficult to see how confused and conflicting was the whole system. It was in fact gradually becoming impossible to differentiate between primary, higher elementary and secondary education. The *Cockerton case* at last, by restricting the board schools to strictly elementary education, made it necessary for the legislature to review the whole position. It was evident that the *Cockerton case* could not be allowed to lower the standard of national education; it was equally evident that a glorified school board system meant the ultimate ruin of all forms of tertiary or university education so far as the masses were concerned. These aspects of the problem were obvious to all who were not blinded by hatred to the established church into refusing aid to the voluntary schools, or who were not members of school boards and believers in the eternal fitness of a higher elementary *cul de sac* training.

In order to place national education upon a sound basis it was necessary that every possible grade of education from the infant classes of elementary schools to the post-graduate classes of the universities should form one continuous system, and that there should be no competitive overlapping between its various parts. It was also necessary that the system should in no way run contrary to the almost universal national belief that christian religious teaching in some form or another, denominational or undenominational, must take a definite place in the education of children. The Board of Education act, 1899, to some extent paved the way for the elaborate national system that is now, under the act of 1902, in a fair way to become effective. The act of 1899 established a board of education to take the place both of the education committee of the Privy Council (known as the Education Department) and the South Kensington Department of Science and Art. It gave to this new board the power to inspect all secondary

schools that desired to be inspected and gave to the county councils the power to pay for such inspection, thus bringing the councils into closer connection with the secondary system. The act also provided for the creation of a consultative committee (consisting as to two thirds of persons representing the views of universities and other bodies interested in education) for the purpose of framing a register of teachers throughout the country of all grades and for the general purpose of advising the Board of Education on technical educational matters. This committee is proving a most effective body, and it will soon be difficult for any school of repute to reject official inspection and for any schoolmaster of standing to withhold his name from the official register. The act also gave the Board of Education the capacity to take over and exercise any powers of the charity commissioners or of the board of agriculture relating to education. The vast powers exercised by the charity commissioners over the secondary endowed schools of the country under the endowed schools act of 1869 and the amending acts, were vested last August, by virtue of this provision, in the Board of Education. The result of this step was to make the Board of Education the supreme authority over both primary and secondary education and to bring it into touch with the county councils in relation to all secondary matters. The next obvious step was to replace the school boards by the county councils (and county borough councils) and thus make the local administrative authority an intermediary in the cases of *all* grades of education between the schools and the Board of Education. This is the great accomplishment, from the educational point of view, of the act of 1902. The school boards in their vain efforts to supply something of the nature of a secondary education were rapidly making confusion worse confounded. By the simple expedient of placing the local secondary authority—the county council—in the place of the school board, the principle of order and development was at once introduced into the national educational system. The supporters of the school boards—men who realized the admirable work that had been done by these boards, but who were unable to grasp the fact that that work could be more efficiently continued by bodies that had the interests of secondary as well as primary education at heart as part of a civic system—opposed the bill with fierce energy, and they were aided by all those who believed that the new bill was unduly helping the elementary denominational or voluntary schools. The government with respect to those schools was in a difficult position. The owners and managers of the schools claimed as of right assistance out of local rates on the ground that they were doing work which if they did not exist would have to be done by new schools built by a school board at great cost. They, however, refused to alter the denominational character of these schools. They declared that the con-

science clause, protecting the religious beliefs of children of other denominations attending the schools, was sufficient. The government had, therefore, the alternative of helping these voluntary schools on terms and thus knitting them forever into the national system, or of building at a cost of £120,000,000 schools to compete with these schools, or of buying them compulsorily at a cost of over £50,000,000 and starting them as undenominational schools. Obviously, the only business-like course was to make terms with the voluntary schools. The bill was fought in the legislature for a period of nine months, but eventually passed, retaining the principles contended for by all economists and educationalists of weight in the country.

I must briefly note the provisions of the act. The first section enacts that every county council and county borough council and the borough council of every non-county borough with a population over 10,000 and the district council of every urban district with a population over 20,000 shall be the local educational authority for elementary education, while the county council and the county borough council are the authorities for higher education. In the case of *all* non-county boroughs and urban districts the borough or district council may supplement the work of the county council by supplying or aiding the supply of, within their financial limits, higher education. In the non-county boroughs with a population of 10,000 and *under,* and urban districts with a population of 20,000 and *under,* the county council, in addition to its authority over higher education, controls elementary education. The act goes on to provide that the local educational authority shall 'take such steps as seem to them desirable, after consultation with the Board of Education, to supply or aid the supply of education other than elementary, and to promote the general coordination of all forms of education.' In order to fulfil this laudable purpose the local educational authority is invested with a rating power for secondary education to enable it to supplement the funds above referred to as ear-marked for secondary education. County borough councils can make any necessary rate for secondary education, but county councils can only make (apart from the consent of the Local Government Board to a higher rate) a rate of twopence in the pound (threepence in certain exceptional cases) while the councils of non-county boroughs and urban districts are able only to make a rate of one penny in the pound for this purpose. The religious aspect of higher education is made the subject of special provisions, and a carefully drafted conscience clause protects all classes of pupils.

Part III. of the act (sections 5–17) deals with elementary education. It abolishes school boards and substitutes the local education authority. This authority, in addition to the power of the old school boards over schools provided out of the rates, is responsible for and has the control of all secular education in these denominational schools

that have not been provided out of the rates and have hitherto been known as 'voluntary schools.' In future the rate-provided schools will be supplied with a body of managers, four of whom will be appointed by the local education authority and two by the minor local authority (such as the parish council), in whose area the school is situated. On the other hand, in the case of the non-provided or 'voluntary schools,' the managing body will consist of four managers, appointed as heretofore by the denomination to which the school belongs and of two managers appointed, as to one by the local educational authority and as to another by the 'minor local authority,' such as the parish council of the parish in which the school is situated. Thus, while for the first time publicly elected persons are included in the managing bodies of the voluntary schools, yet the private and original or foundation managers still retain the controlling voice in all matters of religion, so that there can be no possibility of a change in the denominational character of the school. This was mere justice, since many of these schools have been Church of England, or Wesleyan, or Roman Catholic, or Jewish, as the case may be, for nearly a century. The local education authority has, however, complete control over secular education in these schools. The managers must carry out all its directions as to secular instruction, including any directions with respect to the number and educational qualifications of the teachers to be employed for such instruction, and for the dismissal of any teacher on educational grounds. The local education authority has power to inspect the school, and its consent is required, in relation to the appointment and dismissal of teachers; but an appointment by the managers can only be objected to on educational grounds, while a teacher *can* be dismissed without the consent of the local educational authority, on grounds connected with the giving of religious instruction in the school. The managers of the voluntary school must provide the schoolhouse free of any charge and keep it in good repair subject to fair wear and tear in the course of its use as a public elementary school. Such wear and tear has to be made good by the local educational authority. The religious instruction given in a voluntary school shall be in accordance with the provisions (if any) of the trust-deed on the subject and shall be under the control of the managers with an appeal to the superior denominational authority if such appeal is provided for by the trust deed. Subject as above the local education authority has to maintain and keep efficient all public elementary schools within their area which are necessary (whether 'voluntary schools' or rate-provided schools) and has the control of all expenditure required for that purpose. The provision of new schools, a different system of government grants—paid, not to the managers, but

to the local education authority—and the constitution of education committees of councils having powers under the act are various further salient characteristics of this measure to which it is necessary to draw attention. In the case of the education committees it is to be noticed that the whole educational administrative work will be done by these committees which will possess all the educational powers of the council except that of raising a rate or borrowing money for education purposes.

It is perhaps impossible to exaggerate the importance of this act of Parliament. Doubtless it has certain defects, but they are defects inherent in any act that endeavors to reconcile interests that are apparently in conflict. The political dissenters declared themselves wronged because rate-aid was given to the voluntary schools without a corresponding control by the representatives of the rate payers. Only one third of the managers represent the rate payers in the managing body of a voluntary school, and the fact that the majority of the managers are still private persons is a source of grievance to a certain class of liberals. On the other hand the owners of voluntary schools think themselves aggrieved in the fact that managers, who may not represent the denomination to which the school belongs, should have any word as to the religious teaching. These owners think that the public have the best of the bargain; the public have gained complete control, through the local education authority, over the secular teaching in these schools, while the views of the owners and managers are continually kept before the public by the representatives of the rate payers or the managing body. All the old privacy is lost.

On the whole, however, a fair bargain has been struck. The owners of the schools have a guarantee given them that the denominational character of each school shall be preserved, and they in return have for most purposes (other than religious) handed over the school to a body representing the public—the local education authority, *i. e.*, the education committee of a publicly elected body. An effort all through the act is made to do justice to denominational bodies on the one hand and to secure absolutely efficient and coordinated education on the other, and on the whole the measure may be regarded as the great starting point of a new and beneficent educational system. London does not come within this scheme, but the metropolis is now being dealt with on the same lines by a bill 'to extend and adapt the Education Act, 1902, to London.' The educational authority for London will be the London County Council represented by an education committee composed of members of the council and representatives of the various London borough councils and of various metropolitan educational interests. This central educational body will exercise control over the metropolitan borough councils in their new capacity as managers of all public elementary schools provided by the County Council.

It is proposed that the borough councils shall have the power of appointing and dismissing teachers (though not of fixing their number, qualifications and salary) and of selecting the sites for any new elementary schools that the County Council decide to provide. The bill in these respects may perhaps be altered, and it is possible that members of the council will form a majority (as they do not in the unamended bill) on the education committee. In most other respects it is proposed to bring London within the act of last year and therefore under the final control, for all forms of education, of the Board of Education. However, little is certain yet except that the London school board will pass away and with it that competition between primary and secondary schools which has been the result of one of the less desirable aspects of the work of a board which has done much good and earnest work in London since 1870. Of course, none of the London board schools will cease to exist, nor will one single form of educational activity disappear. Only the name will be changed and the particular characteristics of certain schools will be altered. Schools that ought to be strictly secondary in character will be made secondary, while schools of a primary type will be compelled to keep to that type, but will also be dove-tailed into the nearest strictly secondary school. London will gain immensely by this, though admirers of the London school board system will feel keenly any reversal of the old and ruinous policy of forcing higher grade elementary education into competition with pure secondary education. Gain in efficiency is, however, the only thing to be considered, and there can be no doubt that the London school board has outgrown its functional usefulness and may well be replaced by a body capable of coordinating metropolitan education of all grades.

When the London bill is passed English education, whether primary, secondary, technical or tertiary, will be in a highly satisfactory state as far as machinery is concerned. The putting of this machinery into smooth motion will then be merely a question of time. When this is done the future of England may be regarded without pessimism or distrust. The widest meaning of education itself will gradually enter into the knowledge of the nation and it will be within the power of the poorest to reap harvests of incalculable wealth in hidden lands yet unknown to the masses of the people. Far away lie these lands, beyond the passionate, the stormy, the fretful, the cruel ocean of ignorance. All glory and honor will be to the generation that shall devise fit means of transit across this fearful region. The sea of ignorance imprisons the human race in a narrow land. Across its waters the few pass fitfully, fearfully now; but surely the day is not far distant when the many shall claim in pride and gladness their birthright of passage.

THE DECLINING BIRTH RATE AND ITS CAUSE.

By FREDERICK A. BUSHEE, Ph.D.,
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IN the May number of THE POPULAR SCIENCE MONTHLY Professor Thorndike discusses the question of the low birth rate among college graduates, presenting statistics from New York University, Middlebury College, and Wesleyan University, which confirm the report of President Eliot of Harvard University. These statistics show pretty conclusively that the birth rate among families of college graduates, at least in the east, is not large enough to keep up their numbers, and the question at once arises whether this tendency is confined to the intellectual classes or whether it applies to others as well. In either case it is of the utmost importance to understand the cause of the phenomenon. Let us consider then, first, the evidence of a low birth rate outside the circle of college graduates, and, secondly, let us consider the possible causes of a low birth rate.

The evidence concerning the natural increase of the population in this country is exceedingly meager. In the first place comparatively little attention has been given to the question here, because we have come to think that, though it is a question which France has to wrestle with, it has nothing to do with a new country like the United States. Again, owing to the different conditions existing in different districts, and to the different social conditions in the same district, a solution of the question would require detailed statistics which are not available for any large area of the United States. Very fair results may be obtained, however, by studying the population of a single state or city along national lines. The results which have already been obtained by this method in Massachusetts throw considerable light upon the question of the natural increase of our population.

Mr. Kuczynski, a Washington statistician, has made an exhaustive study of the statistics of Massachusetts and has concluded that the native population of Massachusetts is dying out.* His study extends over the period from 1885 to 1897. He shows, first, that the marriage rate among the natives is much smaller than among the foreign born for all ages up to 45. The marriage rate of unmarried males, 15 years of age and older, is, native born, 47.7; foreign born, 68.9; and for females, native born, 40, foreign born, 56.8. Secondly, the proportion of per-

* *Quarterly Journal of Economics*, November, 1901, February, 1902.

sons married among the natives is much smaller than among the foreign born, and the difference is particularly great at the most fruitful periods of life. Thirdly, the proportion of married women that have never had children is much greater among the natives than among the foreign born. It is one fifth among the natives and two fifteenths among foreigners. Fourthly, the birth rate among married women of child bearing age is much larger among foreign born. The figures are 142.47 per mille for natives and 251.76 for foreign born. Finally, an interesting result for our purpose is that for the period under discussion, 1885–1897, the marriage rate and the proportion of married women were decreasing among the natives and increasing among the foreigners. And the refined birth rates were fairly steady for the natives, but increasing for the foreign born.

As to the question of whether the native population is actually keeping up its numbers or not, after showing the paucity of our vital statistics as compared with those of Berlin, Mr. Kuczynski says, "But as the tables of fecundity of Berlin show that, with an annual special birth rate of ten for every hundred women in child-bearing age, in 1891–95, the births were one ninth behind the number necessary to keep the population of Berlin stationary, it is probable that the native population of Massachusetts, with a special birth rate of 6.3 births for every 100 adult women in child bearing age, and a mortality of the female sex not correspondingly lower than that of Berlin, can not only not hold its own, but is dying out at a considerable pace."* In studies which I have made upon the population of Boston by nationalities† practically the same results were obtained, although there was less opportunity to make a detailed study of the birth rates. The figures for Boston indicate that the negroes and the native whites are failing to keep up their numbers—the former on account of a high death rate and the latter on account of a low birth rate. On the other hand, all the foreign born groups show a natural increase, though the rate of increase varies greatly with the different nationalities. On the whole, the most recently immigrating nationalities have the highest birth rates.

The statistics, although somewhat fragmentary, seem to show that in Massachusetts, and probably also in other sections of the country having similar social conditions, the older part of the population, represented roughly by native Americans, is slowly dying out because of the low birth rate. If this is true the conditions in the older parts of the United States bear a strong resemblance to those in France, except that in the latter country the population as a whole fails to increase, while in this country it is only a section of the population. In the

* *Quarterly Journal of Economics*, February, 1902, p. 184.

† Publication *American Economic Association*, May, 1903.

United States, and even in Massachusetts, the population as a whole is increasing, but the increase is confined for the most part apparently to the immigrating classes. Inasmuch as the failure to increase is confined to only a part of the population in the United States, it is extremely difficult to ascertain the exact situation by statistical means. An insidious loss may be going on in a particular direction and still be undiscovered because of defective mortality statistics.

These statistics put the whole native population of Massachusetts in the same position as college graduates, and the question accordingly seems to be one of the upper class or of the older part of the population and not simply a question of the educated classes.

In the absence of further statistics upon the subject, it will be of assistance to ascertain, by theoretical law if possible, the causes which contribute to these suicidal tendencies in the population. Laws of population have been formulated from similar experiences in other countries, and among these laws we may find one which will throw light upon our own situation.

It will not be worth while to review the common theories of population and show their application to our present conditions. The theory of Malthus, or even that of Spencer, will be of little avail, as the birth rate in the United States is not greatly affected by physical causes. And, although some writers have pointed to a possible biological cause, it is improbable that in a new country like the United States even the older part of the population could, as a class, be losing its fertility, when in so many of the older countries the fertility of the population is still good.

To social causes, primarily, are due the differences in the fecundity of civilized peoples. Therefore I shall present what may be called a social law of population. From the nature of the case any law of population must be exceedingly general, because a great number of conditions directly or indirectly affect the birth rate, and these secondary causes differ in different localities. The law which I am about to consider explains the situation only in a general way. Some of the special conditions which affect the birth rate here I shall discuss later on. This law of population is one formulated by a French student of demography, Arséne Dumont. In brief M. Dumont's theory is that population increases inversely with 'social capillarity.' This expressive phrase is almost self-explanatory. Among progressive peoples a strong tendency exists for men to improve their condition, and in a democratic country society yields somewhat to efforts in this line. If competition is severe it will be necessary for men to make a great effort to raise their standard of living, or sometimes, even to maintain the accustomed standard. Population is regulated by the intensity of the effort made.

Of course the check to population resulting from the desire for social betterment is a purely voluntary one, yet it is a good example of a social law that men under certain conditions will choose to refrain from having large families.

In applying this law it must be borne in mind that conditions vary greatly with different individuals and with different countries. If a man is able to raise his standard of living without great exertion, as is usually the case in a new country, no check to population may be expected. Or, if a man by exceptional abilities is able to maintain a high standard of living with comparative ease, he will not be influenced by the same considerations as the average man. If, on the one hand, men who easily raise their standard of living propagate freely, those who are unable to change their social position at all also propagate freely. In a caste system of society, or in an absolute despotism like that of Russia, the lower classes propagate blindly because they see no possibility of rising. No 'social capillarity' exists for them. In other words population is not held in check by a social law, but by a physical one. It is limited by the means of subsistence, according to the Malthusian law. Even among the lower classes of a great industrial center the same principle acts. Unskilled laborers attain the maximum wage at an early age and increased efforts on their part affect their social condition so little that they do not feel the social check and therefore propagate recklessly from hopelessness. A man in the lowest social class has no social position to lose, and only the best equipped can improve their condition sufficiently to feel the social restriction on population. To advise the laboring classes to limit their numbers in order to improve their condition, as the old economists did, is putting the cart before the horse. When the economic condition of the lowest industrial class improves enough to give its members some hope, they will begin to limit their numbers voluntarily in order further to improve their condition.

If, then, the class that rises easily in the social scale and the class which does not rise at all propagate freely the social check applies to that large class which rises, though only with great effort. It would appear then that in a pure democracy where increased reward always followed increased effort, the population would regulate itself automatically, because increased population would increase competition and that would bring about the social check. Its application to some of our large cities will be readily understood by those who are acquainted with the social conditions existing in them. Their enormous increase of population has increased competition to such an extent that only the best equipped—as compared with other members of the same class, not with inferior classes—can easily maintain the standard of living

set by their own particular classes. Consequently the cares of a family are deferred. If one enters the lodging houses in the south and west ends of Boston, for example, one will find a large class of lodgers from northern New England and from the British Provinces, the majority of whom are not married and never will be. This class represents a part of the population which is refraining from marriage in order to keep up its social position. In the words of M. Dumont, 'social capillarity' is so strong that they refrain from marriage. This state of affairs is unfortunate for the future good of the city. Cities have come to depend upon fresh blood from the country to reinforce their declining stock, and there is no reason to believe that former immigrants from rural sections found it necessary to refrain from marriage as the present immigrants do. In other words, a change is taking place in the character of the population of large cities which only the next generation will realize. Cities of the present time are making use of rural Americans and also of the children of rural Americans who came to the city about the middle of the nineteenth century. In the next generation the proportion of children of rural immigrants will be greatly reduced, and the probabilities are that the largest cities will offer small inducements for the immigration of rural Americans.

With this application of the general law of population I pass to the discussion of two conditions in the eastern part of the United States which tend to intensify the action of this law and make the birth rate in this new country as low as it is in some of the old European countries. First, the increased competition which naturally results from a growing population has been augmented by the entrance of women into industrial pursuits. As women find fewer opportunities for marriage, they throw themselves into industrial life, and by their increased competition make the possibility of marriage even more remote. As writers have frequently noted the depression of wages resulting from the competition of women, however, I will pass on to the second phenomenon which affects the social law of population—that is, immigration. Competition resulting from increased population is much more serious if it is caused by the incoming of classes on a different social plane. Irish, Italian, and Jewish immigrants compete indirectly, and frequently directly with American labor, yet these immigrants live in a different world and under different conditions from the American laborer. Most foreigners form a stratum below Americans. Between the lodging house and the tenement is a wide gap which is not paralleled by an industrial separation. Americans in lodging houses are not attempting so much to raise their standard as they are to retain the accustomed standard of their homes and to save themselves from falling into the social position of the foreign population.

When Francis Walker was director of the United States Census, he went so far as to maintain that the population of the country would have been just as large if there had been no foreign immigration, since the older American elements would then have multiplied much more rapidly than they have. This is without doubt an extreme statement, yet it is true that the multiplication of foreign peoples has seriously checked the growth of the old American stock. It may be that in the distant future the mixture of all the European peoples will produce a race superior to any we have yet seen. It is well to bear in mind, however, that in forming a race of unknown value, there is being sacrificed a race of acknowledged superiority in originality and enterprise.

The relative decrease of the native stock is, however, far more noticeable than its absolute decrease. For example, from the last statistics available for Boston it appears that the Russian Jews increased by propagation 25 per cent. between 1890 and 1895, and the Italians increased 21 per cent. during the same period, while the native born decreased slightly. And this phenomenal natural increase of the Italians and the Jews takes on an added significance from the fact that during the same period of five years the Italians increased 67 per cent. and the Jews 51 per cent. by immigration.

Foreign immigrants, after being in this country for some time, seem to be affected in much the same way as the native born. However, the pressure of competition from recent immigration does not affect them so much as it does the greater part of the native born, for a greater social cleavage exists between the rural Americans and foreign immigrants than between the old and new immigrants. Yet the Irish and the Germans, at least in Boston, have a much smaller birth rate than the Italians and the Jews, and also than they themselves had in 1850.

Mr. Kuczynski, in his study of Massachusetts, continually contrasts the statistics for the native born with those for the foreign born, but there is more than a contrast, there is a causal connection. The rapid influx of foreigners and their unrestrained increase necessarily affects the native born. And the evil effects arise from the competition in industrial pursuits of people of different social standards. If the immigrants were of the same ideals and standards as the native Americans, the results would be different. The increased competition would bring about a lowering of the birth rate, but the restraint would be mutual to both natives and foreigners. In the present case, however, where the standards are different the prudential restraint is exercised only by the group which has a social standard to maintain. Is it not from a sense of self preservation that castes tend to be formed in a society consisting of distinct social classes, so that each caste shall have its separate sphere of employment and competition between castes

shall be eliminated as much as possible? Otherwise the upper classes would tend to be obliterated by the competition of the lower classes.

To sum up, then, we may say that the study of the statistics available in the light of recent theories of population gives us a reasonable understanding of the natural increase of the population. Statistics show that in Massachusetts at least the native population which includes the upper classes is losing ground. That this loss is due to the effort necessary to maintain or raise the social position caused by strong competition is shown by the fact that the marriage rate as well as the birth rate is low. This competition is caused largely by the influx of foreigners who tend to compete with the natives, but do not share with them the dread of lowering the social standard. If the increased population came wholly from within the state, the population would tend to regulate itself automatically, but when the increase is largely imposed upon a state from without, and this foreign element reproduces itself rapidly it may have a serious influence upon the native population without being very apparent. The economic question is by no means the most important one to consider in the problem of immigration. It is a race question and the birth rate shows the racial group that is to survive. If, however, it is found that the stratum of society which has the highest development tends to be blotted out by the increase of the lower strata, the cause of progress will demand that the course of natural selection be interfered with by removing the continual external pressure on the native stock.

HERTZIAN WAVE WIRELESS TELEGRAPHY. III.

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WE have to consider in connection with this part of the subject the dielectric strength of air under different pressures and for different thicknesses. It was shown by Lord Kelvin, in 1860, that the dielectric strength of very thin layers of air is greater than that of thick layers.* The electric force, reckoned in volts per centimeter, required to pierce a thickness of air from two to ten millimeters in thickness, at atmospheric pressure, may be taken at 30,000 volts per centimeter. The same force in electrostatic units is represented by the number 100, since a gradient of 300 volts per centimeter corresponds to a force of one electrostatic unit. It appears also that for air and other gases, there is a certain minimum voltage (approximately 400 volts) below which no discharge takes place, however near the conducting surfaces may be approximated. In this particular practical application, however, we are only concerned with spark lengths which are measured in millimeters or centimeters, lying say between one or two millimeters and five or six centimeters. Over this range of spark length we shall not generally be wrong in reckoning the voltage required to produce a spark between metal balls in air at the ordinary pressure to be given by the rule:

Disruptive voltage = 3000 × *spark gap length in millimeters.*

If, however, the air pressure is increased above the normal by including the spark balls in a vessel in which air can be compressed, then the spark length corresponding to a given potential difference very rapidly decreases. Mr. F. J. Jervis-Smith† found that by increasing the air pressure from one atmosphere to two atmospheres round a pair of spark balls, he reduced the spark length given by a certain voltage from 2.5 cm. to 0.75 cm.

Professor R. A. Fessenden has also made some interesting observations on the effect of using compressed air round spark gaps. He

* See *Proc. Roy. Soc.*, London, February 23 and April 12, 1860; or reprint of papers on electrostatics and magnetism, p. 247.

† See *Phil. Mag.*, August, 1902, Vol. IV., p. 224, 6th Series. Mr. Jervis-Smith has also described an experiment to show how much the use of compressed air round a spark gap is of advantage in working an ordinary Tesla coil. In his British specification No. 12,039 of 1896, Mr. Marconi had long previously mentioned the use of compressed air round the spark gap.

found that if a certain voltage between metal surfaces would yield a spark four inches in length, at the ordinary pressure of the air, if the spark balls were enclosed in a cylinder, the air round them compressed at 50 lbs. per square inch, the spark length for the same potential difference of the balls was only one quarter of an inch, or one sixteenth of its former value.

The writer has also made experiments with an apparatus designed to study the effect of compressed air round the spark gap. The experimental arrangements are as follows: A ten-inch induction coil has one of its terminals connected to the internal coating of a battery of Leyden jars. The external coating is connected through the primary coil of an oscillation transformer with the other secondary terminal of the coil, and these secondary terminals are also connected to a spark gap consisting of two brass balls enclosed in a glass vessel into which air can be forced by a pump, the air pressure being measured by a gauge. The balls in the glass vessel are set at a distance of about three millimeters apart. The secondary circuit of the oscillation transformer is connected to another pair of spark balls, the distance of which can be varied.

Suppose we begin with the air in the glass vessel containing the balls connected to the secondary terminals of the induction coil, which may be called the secondary balls, at atmospheric pressure, and create oscillatory discharges in the primary coil of the oscillation transformer, we have a spark between the balls, which may be called the tertiary balls, connected to the secondary terminals of the oscillation transformer. If the secondary balls are placed, say three millimeters apart, the air in the glass vessel enclosing them being at the ordinary atmospheric pressure, then with one particular arrangement of jars used, a spark twenty-five or twenty-six millimeters long between the tertiary balls will take place. Suppose then we increase the pressure of the air round the secondary balls, pumping it up by degrees to 10, 20, 30, 40 and 50 lbs., per square inch, above the atmospheric pressure. We find that the spark between the tertiary balls will gradually leap a greater and greater distance, and when the pressure of the air is 50 lbs. per square inch, we can obtain a fifty-millimeter spark between the tertiary balls, whereas when the air in the glass vessel is at atmospheric pressure, we can only obtain a spark between the tertiary balls of half that length.

This experiment demonstrates that the effect of compressing the air round the secondary terminals of the induction coil is to greatly increase the difference of potential between these balls before the spark passes. In fact, it requires about double the voltage to force a spark of the same length through air compressed at 50 lbs. on the square inch that it does to make a spark of identical length between the

same balls in air at normal pressure. This shows that there is a very great advantage in taking the discharge spark in compressed air. A better effect can be produced by substituting dry gaseous hydrochloric acid for air at ordinary pressures.

One other incidental advantage is that the noise of the spark is very much reduced. The continual crackle of the discharge spark of the induction coil in connection with wireless telegraphy is very annoying to sensitive ears, but in this manner we can render it perfectly silent.

Professor Fessenden also states that when the spark balls are surrounded by compressed air, and if one of the balls is connected with a radiator, the compression of the air, although it shortens the spark gap corresponding to a given voltage, does not in any way increase the radiation. When, however, the air in the spark ball vessel is compressed to 60 lbs. in the square inch, there is a marked increase in the effective radiation, and at 80 lbs. per square inch the energy emitted in the form of waves is nearly three and a half times greater than at 50 lbs., the potential difference between the balls remaining the same.

This effect is no doubt connected with the fact that the production of a wave, whether in ether or in any other material, is not so much dependent upon the absolute force applied as upon the suddenness of its application. To translate it into the language of the electronic theory, we may say that the electron radiates only whilst it is being accelerated, and that its radiating power, therefore, depends not so much upon its motion as upon the rate at which its motion is changing.

The advantage in using compressed air round the spark gap is that we can increase the effective potential difference between the balls without rendering the spark non-oscillatory. In air of the ordinary pressure there is a certain well-defined limit of spark length for each voltage, beyond which the discharge becomes non-oscillatory, but by the employment of spark balls in compressed air, we can increase the potential difference between the balls corresponding to a given distance apart before a discharge takes place, or employ higher potentials with the same length of spark gap. In addition to this, we have, perhaps, the production of a more effective radiation, as asserted by Fessenden, when the air pressure exceeds a certain critical value.

The next element which we have to consider in the transmitting arrangements is a condenser of some kind for storing the energy which is radiated at intervals. Where a condenser other than the aerial is employed for storing the electric energy which is to be radiated by the aerial, some form of it must be constructed which will withstand high potentials. As the dielectric for such a condenser, only two materials seem to be of any practical use, viz., glass and micanite.

Glass condensers in the form of Leyden jars have been extensively employed, but they have the disadvantage that they are very bulky in proportion to their electrical capacity. The instrument maker's quart Leyden jar has a capacity of about one five hundredth of a microfarad, but it occupies about 150 cubic inches or more. Professor Braun has employed in his transmitting arrangements condensers consisting of small glass tubes like test tubes, lined on the inside and outside with tinfoil, which are more economical in space. The author has found that condensers for this purpose are best made of sheet glass about one eighth or one tenth of an inch in thickness, coated to within one inch of their edge on both sides with tinfoil, and arranged in a vessel containing resin or linseed oil, like the plates of a storage battery. M. d'Arsonval has employed micanite, but although this material has a considerably higher dielectric strength than glass, it is much more expensive to obtain a given capacity by means of micanite than by glass, although the bulk of the condenser for a given capacity is less.

To store up a certain amount of electric energy in a condenser, we require a certain definite volume of dielectric, no matter how we may arrange it, and the volume required per unit of energy is determined by the dielectric strength of the material. Thus, for instance, ordinary sheet glass can not be safely employed with a greater electric force than is represented by 20,000 volts for one tenth of an inch in thickness, or say a potential gradient of 160,000 volts per centimeter. This is equivalent to an electric force of about 500 electrostatic units. This may be called the safe-working force. The electrostatic capacity of a condenser formed of two metal surfaces a foot square separated by glass three millimeters in thickness is between 1/360 and 1/400 of a microfarad. If this condenser is charged to 20,000 volts, we have stored up in it half a joule of electric energy, and the volume of the dielectric is 270 cubic centimeters. Hence to store up in a glass condenser electric energy represented by one joule at a pressure of 20,000 volts, we require 500 cubic centimeters of glass, and it will be found that if we double the pressure and double the thickness of the glass, we still require the same volume.* Hence in the construction of high tension condensers to store up a given amount of energy, the economical problem is how to obtain the greatest energy-storing capacity for the least money. Glass fulfils this condition better than any other material. Although some materials may have very high dielectric strength, such as paper saturated with various oils, or resins, yet they can not be used for the purpose of making condensers to yield oscillatory discharges,

* This energy storage is at the rate of 44 foot-pounds per cubic foot of glass. This figure shows what a relatively small amount of energy is capable of being stored up in the form of electric strain in glass. In the case of an air condenser, it is only stored at the rate of one foot-pound per cubic foot.

because the oscillations are damped out of existence too soon by the dielectric.

In arranging condensers to attain a given capacity, regard has to be taken of the fact that for a given potential difference there must be a certain total thickness of dielectric, and that if condensers of equal size are being arranged in parallel, it adds to their capacity, whilst joining them in series divides their capacity. If N equal condensers or Leyden jars have each a capacity represented by C and if they are joined n in series and m in parallel, the joint capacity of the whole number is mC/n, where the product $mn = N$.

Passing on next to the consideration of oscillation transformers of various kinds—these are appliances of the nature of induction coils for transforming the current or electromotive force of electrical oscillations in a required ratio. These coils are however destitute of any iron core, and they generally consist of coils of wire wound on a fiber, wooden or ebonite frame, and must be immersed in a vat of oil to preserve the necessary insulation. No dry insulation of the nature of indiarubber or guttapercha will withstand the high pressures that are brought to bear upon the circuits of an oscillation transformer. In constructing these transformers, we have to set aside all previous notions gathered from the design of low frequency iron core transformers. The chief difficulty we have to contend against in the construction of an effective oscillation transformer is the inductance of the primary circuit and the magnetic leakage that takes place. In other words, the failure of the whole of the flux generated by the primary circuit to pass through or be linked with the secondary circuit. Mr. Marconi has employed an excellent form of oscillation transformer, in the design of which he was guided by a large amount of experience. In this transformer the two circuits are wound round a square wooden frame. The primary circuit consists of a number of strands of thick insulated cable laid on in parallel, so that it consists of only one turn of a stranded conductor. The secondary circuit consists of a number of turns, say ten to twenty, of thinner insulated wire laid over the primary circuit and close to it, so that the transformer has the transformation ratio of one to ten or one to twenty. In the arrangements devised and patented by Mr. Marconi, these two circuits, with their respective capacities in series with them, are tuned to one another, so that the time-period of each circuit is exactly the same, and without this tuning the device becomes ineffective as a transformer.* There is no advantage in putting a number of turns on the primary circuit, because such multiplication simply increases the inductance, and, therefore, diminishes the primary current in the same ratio which it multiplies the

* See British specification No. 7,777 of 1900—G. Marconi. 'Improvements in Apparatus for Wireless Telegraphy.'

turns, and hence the magnetic field due to the primary circuit remains the same. Where it is desired to put a number of turns upon a coil, and yet at the same time keep the inductance down, the writer has adopted the device of winding a silk or hemp rope well paraffined between the turns of the circuit, so as to keep them further apart from one another, and as the inductance depends on the turns per centimeter, this has the effect of reducing the inductance.

The next and most important element in any transmitting station is the aerial or radiator, and it was the introduction of this element by Mr. Marconi which laid the foundation for Hertzian wave telegraphy as opposed to mere experiments with the Hertzian waves. We may consider the different varieties of aerial which have been evolved from the fundamental idea. The simple single Marconi aerial consists of a bare or insulated wire, generally about 100 or 150 feet in length, suspended from a sprit attached to a tall mast. As these masts have generally to be erected in exposed positions, considerable care has to be taken in erecting them with a large margin of strength. To the end of a sprit is attached an insulator of some kind which may be a simple ebonite rod, or sometimes a more elaborate arrangement of oil insulators, and to the lower end of this insulator is attached the aerial wire. As at the top of the aerial we have to deal with potentials capable sometimes of giving sparks several feet in length, the insulation of the upper end of the aerial is an important matter.

In the original Marconi system, the lower end of the aerial was simply attached to one spark ball connected to one terminal of the induction coil, and the other terminal and spark ball were connected to the earth. In this arrangement, the aerial acted not only as radiator, but as energy-storing capacity, and as already explained, its radiating power was on that account limited. The earth connection is an important matter. For long distance work, a good earth is essential. This earth must be made by embedding a metal plate in the soil, and many persons are under the impression that the efficiency of the earth plate depends upon its area, but this is not the fact. It depends much more upon its shape, and principally upon the amount of its 'edge.' It has been shown by Professor A. Tanakadate, of Japan, that if a metal plate of negligible resistance is embedded in an infinite medium having a resistivity r, the electrical conductance of this plate is equal to $4\pi/r$ times the electrostatic capacity of the same plate placed in a dielectric of infinite extent. Hence in designing an earth plate, we have to consider not how to give it the utmost amount of surface, but how to give it the greatest electrostatic capacity, and for this purpose it is far better to divide a given amount of metal into long strips radiating out in different directions, rather than to employ it in the form of one big square or circular plate.

The importance of the 'good earth' will have been seen from our discussion on the mode of formation of electric waves. There must be a perfectly free access for the electrons to pass into and out of the aerial. Hence if the soil is dry, or badly conductive in the neighborhood, we have to go down to a level at which we get a good moist earth. In fact, the precautions which have to be taken in making a good earth for Hertzian wave telegraphy are exactly those which should be taken in making a good earth for a lightning conductor.

Whilst on the subject of aerials, a word may be said on the localization of wireless telegraph stations on the Marconi system. For reasons which were explained previously, the transmission of signals is effected more easily over water than over dry land, and it is hindered if the soil in the neighborhood of the sending station is a poor conductor. Hence all active Hertzian wave telegraph stations, like all active volcanoes, are generally found near the sea. In those cases in which a multiple aerial has to be put up consisting of many wires, one mast may be insufficient to support the structure, and several masts arranged in the form of a square or a circle have to be employed. The illustrated papers have reproduced numerous pictures of the Marconi power stations at Poldhu in Cornwall, Glace Bay in Nova Scotia, and Cape Cod in the United States. In these stations, after preliminary failures to obtain the necessary structural strength with ordinary masts, tall lattice girder wooden towers have been built, about 215 feet in height, well stayed against wind pressure, and which so far have proved themselves capable of withstanding any storm of wind which has come against them.

An important question in connection with the sending power of an aerial is that of the relation of its height to the distance covered. Some time ago Mr. Marconi enunciated a law as the result of his experiments, connecting these two quantities, which may be called Marconi's Law. He stated that the height of the aerial to cover a given distance, other things remaining the same, varies as the square root of the distance. Let D be the distance and let L be the length of the aerial, then if both the transmitting and receiving aerial are the same height, we may say that D varies as L^2. This relation may be theoretically deduced as follows: Any given receiving apparatus for Hertzian wave telegraphy requires a certain minimum energy to be imparted to it to make it yield a signal. If the resistance and the capacity of the receiver is taken as constant, this minimum working energy is proportional to the square of the electromotive force set up in the receiving aerial by the impact on it of the electric waves. This electromotive force varies as the length of the receiving aerial, and as the magnetic force due to the wave cutting across it, and the magnetic force varies as the current in the transmitting aerial, and

therefore for any given voltage varies as the capacity, and therefore as the length of the transmitting aerial. If, therefore, the transmitting and receiving aerial have the same length, the minimum energy varies as the square of the electromotive force in the receiving aerial, and therefore as the fourth power of the length of either aerial, since the electromotive force varies as the product of the lengths of the aerials. Hence when the distance between the aerials is constant, the minimum working energy varies as the fourth power of the height of either aerial, but when the lengths of the aerials are constant, the energy caught up by the receiving aerial must vary inversely as the square of the distance D between the aerials. Hence if we call e this minimum working energy, e must vary as $1/D^2$ when L is constant, or as L^4 when D is constant, and since e is a constant quantity for any given arrangements of receiver and transmitter, it follows that when the height of aerial and distance vary, the ratio L^4/D^2 is constant, or, in other words, D^2 varies as L^4 or D varies as L^2, *i. e.*, distance varies as the square of the height of the aerial, which is Marconi's Law. The curve therefore connecting height of aerial with sending distance for given arrangements is a portion of a parabola.

Otherwise, the law may be stated in the form $L = a\sqrt{D}$, where a is a numerical coefficient. If L and D are both measured in meters, then for recent Marconi apparatus as used on ships $a = 0.15$, roughly. (See a report on experiments made for the Italian navy 1900–1901, by Captain Quintino Bonomo—'Telegrafia senza fili,' Rome, 1902.)

This law, however, must not be used without discretion. After Mr. Marconi had transmitted signals across the British Channel, some people, forgetting that a little knowledge is a dangerous thing, predicted that aerials a thousand feet in height would be required to signal across the Atlantic, but Mr. Marconi has made such improvements of late years in the receiving arrangements that he has been able to receive signals over three thousand miles in 1903, with aerials only thirty-three per cent. longer than those which, in 1899, he employed to cover twenty miles across the British Channel.

We turn, in the next place, to the consideration of those devices for putting more power into the aerial than can be achieved when the aerial itself is simply employed as the reservoir of energy. Professor Braun of Strasburg, in 1899, described a method for doing this by inducing oscillations in the aerial by means of an oscillation transformer, these oscillations being set up by the discharges from a Leyden jar or battery of Leyden jars, which formed the reservoir of energy. The induction coil is employed to produce a rapidly intermittent series of electrical oscillations in the primary coil of an oscillation transformer by the discharge through it of a Leyden jar. Mr. Marconi

immensely improved this arrangement, as described by him in a lecture given before the Society of Arts, on May 17, 1901, by syntonizing the two circuits and making the circuit, consisting of the capacity of the aerial and the inductance of the secondary circuit of the oscillation transformer, have the same time-period as the circuit consisting of the Leyden jars, or energy-storing condenser, and the primary circuit of the oscillation transformer, and by so doing immensely added to the power and range of the apparatus.

Starting from these inventions of Braun and Marconi, the author devised a double transmission system in which the oscillations are twice transformed before being generated in the aerial, each time with a multiplication of electromotive force, and a multiplication of the number of groups of oscillations per second. This arrangement can best be understood from the diagram (see Fig. 15).

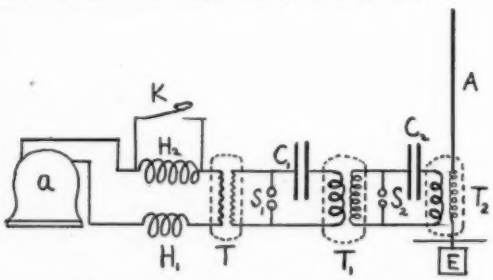


FIG. 15. ALTERNATING CURRENT DOUBLE TRANSFORMATION POWER PLANT FOR GENERATING ELECTRIC WAVES (Fleming). *a*, alternator; H_1H_2, choking coil; *K*, signaling key; *T*, step-up transformer; S_1S_2, spark gap; C_1C_2, condensers; T_1T_2, oscillation transformers; *A*, aerial; *E*, earthplate.

In this case, a transformer T or transformers, receive alternating low frequency current from an alternator a, being regulated by passing through two variable choking coils, H_1 and H_2, so as to control it. This alternating current is transformed up from a potential of two thousand to twenty, forty or a hundred thousand, and is employed to charge a large condenser C_1, which discharges across a primary spark gap S_1 through the primary coil of an oscillation transformer T_1. The secondary circuit of the oscillation transformer is connected to a second pair of spark balls S_2, which in turn are connected by a secondary condenser C_2, and the primary circuit of a third transformer T_2, and the secondary circuit of this last transformer are inserted between a Marconi aerial A and the earth E. When all these circuits are tuned to resonance by Mr. Marconi's methods, we have an enormously powerful arrangement for creating electric waves, or rather trains of electric waves, sent out from the aerial, and the oscillations are controlled and the signals made by short-circuting one of the choking coils.

Another transmitting arrangement, which involves a slightly different principle, and employs no oscillation transformer, is one due

also to Professor Braun. In this case, a condenser and inductance are connected in series to the spark balls of an induction coil, and oscillations are set up in this circuit. Accordingly, there are rapid fluctuations of potential at one terminal of the condenser. If to this we connect a long aerial, the length of which has been adjusted to be one quarter of the length of wave corresponding to the frequency, in other words, to make it a quarter wave resonator, then powerful oscillations will be accumulated in this rod. The relation between the height (H) of the aerial and the frequency, is given by the equation $3 \times 10^{10} = 4nH$, where n is the frequency of the oscillations and H the height of the aerial in centimeters. The frequency of the oscillations is determined by the capacity (C) and inductance (L) of the condenser circuit, and can be calculated from the formula

$$n = \frac{5{,}000{,}000}{\sqrt{C\,(\text{in mfds.}) \times L\,(\text{in cms.})}}.$$

That is, the frequency is obtained by dividing into the number 5,000,000, the square root of the product of the capacity in microfarads, and inductance in centimeters, of the condenser circuit. It will be found, on applying these rules, that it is impossible to unite together any aerial of a length obtainable in practise with a condenser circuit of more than a very moderate capacity. It has been shown that for an aerial two hundred feet in height the corresponding resonating frequency is about one and a quarter million.* As we are limited in the amount to which we can reduce the inductance of a discharge circuit, probably to something like a thousand centimeters, a simple calculation shows that the largest capacity we can employ is about a sixtieth of a microfarad. This capacity, even if charged at 60,000 volts, would only contain thirty joules of energy, or about 22.5 foot-pounds, which is a small storage compared to that which can be achieved when we are employing the above described methods, which involve the use of an oscillation transformer. In such a case, however, it is an advantage to employ a spark gap in compressed air, because we can then raise the voltage to a much higher value than in air of ordinary pressure without lengthening the spark so much as to render it non-oscillatory.

When employing methods involving the use of an oscillation transformer, it is possible to use multiple aerials having large capacity, and hence to store up a very large amount of energy in the aerial, which is liberated at each discharge. The most effective arrangement is one

* That this number really does represent the order of this oscillation frequency in an aerial has been shown by C. Tissot, *Comptes Rendus*, 132, p. 763, March 25, 1901, by photographs taken of the oscillatory spark of a Hertzian wave telegraphic transmitter. (See *Science Abstracts*, Vol. IV., Abs. 1518.) He found frequencies from 0.5 million to 1.6 million.

in which the radiator draws off gradually a large supply of energy from a non-radiating circuit, and so sends out a true train of waves, and not mere impulses, into the ether, and as we shall see later on, it is only when the radiation takes place in the form of true wave trains that anything like syntony can be obtained.

There are a number of variants of the above methods of arranging the radiator and associated energy-storing in circuit. Descriptions of these arrangements will be found in patents by Mr. Marconi, Professor Slaby and Count von Arco, Sir Oliver Lodge, Dr. Muirhead, Professor Popoff, Professor Fessenden and others. In all cases, however, they are variations of the three simple forms of radiator already described.

Returning to the analogy with the air or steam siren suggested at the commencement of this article, the reader will see, in the light of the explanations already given, that all parts of the air wave producing apparatus have their analogues in the electrical radiator as used in Hertzian wave telegraphy. The object in the one case is to produce rapid oscillations of air particles in a tube, which result in the production of an air wave in external space; in the other case, the arrangement serves to produce oscillations of electrons or electrical particles in a wire, the movements of which create a disturbance in the ether called an electrical wave. Comparing together, item by item, it will be seen, therefore, that the induction coil or transformer used in connection with electric wave apparatus is analogous to the air pump in the siren plant. In the electrical apparatus, this electron pump is employed to put an electrical charge into a condenser; in the air wave apparatus, the air pump is employed to charge an air vessel with high pressure air. From the electrical condenser the charge is released in the form of a series of electrical oscillations, and in the air wave producing appliance, the compressed air is released in the form of a series of intermittent puffs or blasts. In the electrical wave producing apparatus, these electrical oscillations in the condenser circuit are finally made to produce other oscillations in an air wire or open circuit, just as the puffs of air finally expend themselves in producing aerial oscillations in the siren tube. Finally, in the one case we have a series of air waves and in the other case, a series of electrical waves. These trains of electric waves or air waves, as the case may be, are intermitted into long and short groups, in accordance with the signals of the Morse alphabet, and therefore the Hertzian wave transmitter, in whatever form it may be employed, when operated by means of a Marconi aerial, is in fact an electrical siren apparatus, the function of which is to create periodic disturbances in the universal ether of the same character as those which the siren produces in atmospheric air.

(To be continued.)

DISCUSSION AND CORRESPONDENCE.

THE BIRTH RATE IN FICTION.

As the question of the size of family appears to be much discussed just now, I should like to call attention to the low birth rate in novels and plays, which, united as it is with a high death rate, will inevitably lead to the rapid extermination of the hero and heroine. I am under the impression also that the birth rate is decreasing, and while families of a respectable size may be found occasionally in Thackeray and Dickens, they scarcely exist in Meredith, Hardy and James. Although, so far as I am aware, attention has never been called to the alarming conditions, their existence will be recognized readily by readers of novels and play-goers. It will suffice to refer to two novels, which I think are fairly typical—'Vanity Fair' and 'Beauchamp's Career.'

Becky Sharp was an only child, nor do we hear of uncles or aunts. 'Vanity Fair' is a novel without a hero. Sir Pitt Crawley, twice married, has four children, his brother five and his sister none; so there is an average family of three, just sufficient to maintain that questionable line. Osborne and Dobbin each have two sisters, and we have again the family required for a stationary population. The Sedley family consists of brother and sister. In the next generation, however, things are worse. Amelia has two husbands and two children, Becky one child, Sir Pitt one and Josh none. This is apparently an average family of 1.83, which is almost exactly that of the Harvard graduates, according to President Eliot.

In 'Beauchamp's Career' Nevil is an only child and leaves a child to survive him; Everard Romfrey, marrying childless Mrs. Culling, has one child who dies in infancy; his brother has none; old Mrs. Beauchamp has none. Austin, Baskelett, Lydiard and Dr. Shrapnel leave no posterity. Of the three heroines, Jenny and Cecilia are only children; Renée is of the typical French family of two, but has herself no children. This is obviously a very bad state of affairs—an average family of one half child and a net fertility of only 0.43. As these statistics have been collected in large measure from a fallible memory, they may not be exactly correct, and they may not be entirely representative, but I am confident that they would be substantially confirmed by more accurate and extensive data. They certainly foretell the rapid extermination of the population of the novel.

The conditions appear to be still worse in the drama. It is true that here the marriage rate is high, and something may be left to the imagination. But Hamlet, Macbeth, Othello and Romeo have no lines of descent, nor does Lear, though he has three daughters. In the current play the woman with a past may occasionally have a child; she certainly never has the average family of four to five; but her extermination is not so deplorable.

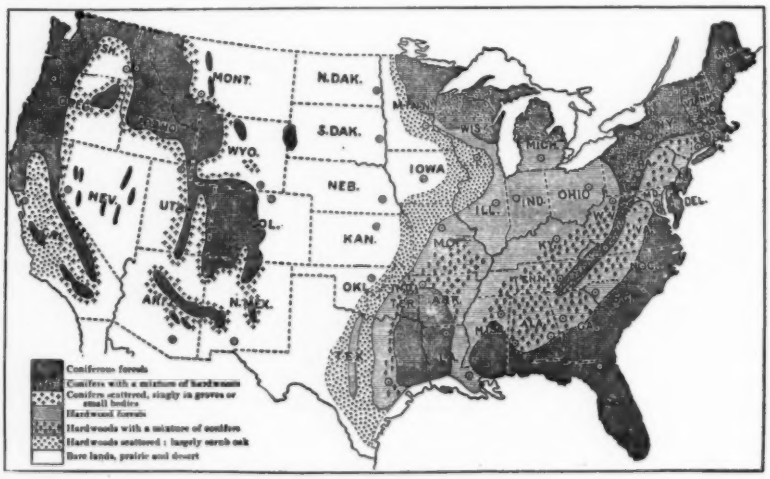
C.

SCIENTIFIC LITERATURE.

FORESTRY.

THE people of the country are rapidly awakening to the immense economic importance of our forests and to the dangerous rapidity with which they are being exterminated. Germany and other countries have long maintained strict forestry systems and schools for foresters; our own resources were so great that there seemed to be no need of economy. But we are now told that the forests under present methods will scarcely last for thirty years, and there is a general demand for more knowledge and better management. In the past few years the Bureau of Forestry under the national government has grown rapidly, the appropriation for investigation having increased from $80,000 in 1901 to $254,000 for the present year. Schools of forestry have been established at Cornell, Yale and Harvard—we may be sure that New York state will soon repent its attitude toward the school at Cornell—and there is a general awakening of interest in the whole subject.

Under these circumstances a little book recently issued by Ginn and Company, entitled 'First Book of Forestry,' is more deserving of notice than other works of greater pretensions. The author, Mr. Filbert Roth, of the Bureau of Forestry, is an authority on the subject, and is able to put it in a simple and interesting form. The book is just what is needed as a tract, and it is to be hoped that it will be widely read.



FOREST MAP OF THE UNITED STATES.

THE PROGRESS OF SCIENCE.

THE BOSTON MEETING OF THE NATIONAL EDUCATIONAL ASSOCIATION.

It is usual for each meeting of the National Educational Association to show an attendance and to claim a success surpassing its predecessors, but the recent Boston meeting established a record that has not hitherto been approached and that will not soon be challenged. It is said that there was a registration of thirty thousand, an assemblage of teachers larger than the world has hitherto seen. Boston is no longer without rival as an intellectual center, but its preeminence in the history of education is maintained, and the intellectual and educational interests of the city are not submerged and hidden to such an extent as is the case in New York, Washington, Philadelphia and Chicago. It is thus the city which has the most to attract a great convention of teachers.

The meetings of the National Educational Association are, in a large measure, an excursion or picnic, the interest of the city and the journey counting for more than the program. There are few or no sessions in the afternoon, not more than half the members attend the sectional meetings in the morning, and not more than one tenth the general evening sessions after the first day. This is quite as it should be, for the teachers from all over the country gain much from travel, sightseeing and social exchange, whereas the programs do a good deal of threshing over of old straw. It is, however, a great stimulus for these teachers to see and hear their leaders; and it was worth going to Boston to listen to the president of the association, President Eliot, of Harvard University, who is without peer as a presiding officer and speaker.

In his presidential address entitled 'The New Definition of the Cultivated Man,' Dr. Eliot—who, it may be called to mind, was a professor of chemistry before he became the greatest college president and educational leader of the country—laid stress on the fact that the scientific method has been the means of the wonderful widening of the intellect that has occurred during the past hundred years and is as necessary for culture as are the humanities; but no special language or literature, such as Latin or Greek, is now essential, English having become incomparably the most extensive and various and the noblest of literatures. After referring to a work of Zola's, Dr. Eliot said:

> Contrast this kind of constructive imagination with the kind which conceived the great wells sunk in the solid rock below Niagara that contain the turbines that drive the dynamos, that generate the electric force that turns thousands of wheels and lights thousands of lamps over hundreds of square miles of adjoining territory; or with the kind which conceives the sending of human thoughts across three thousand miles of stormy sea instantaneously on nothing more substantial than ethereal waves. There is going to be room in the hearts of twentieth century men for a high admiration of these kinds of imagination, as well as for that of the poet, artist or dramatist. It is one lesson of the nineteenth century, then, that in every field of human knowledge the constructive imagination finds play—in literature, in history, in theology, in anthropology and in the whole field of physical and biological research. That great century has taught us that, on the whole, the scientific imagination is quite as productive for human service as the

literary or poetic imagination. The imagination of Darwin or Pasteur, for example, is as high and productive a form of imagination as that of Dante, of Goethe, or even of Shakespeare, if we regard the human uses which result from the exercise of imaginative

PRESIDENT CHARLES W. ELIOT.

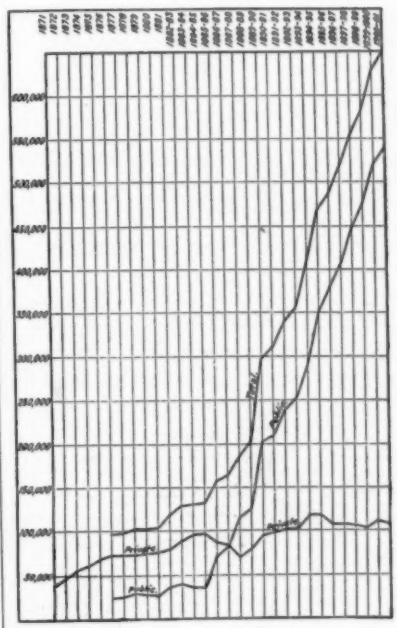
powers, and mean by human uses not meat and drink, clothes and shelter, but the satisfaction of mental and spiritual needs.

There were some three hundred speakers announced on the official program, a few of whom addressed the general evening sessions, while the others took part in the departmental sections for elementary, secondary and higher education, science, normal schools, school administration, physical education, defective children, Indian education, business, art, music, libraries, child study and kindergarten. The discussion of the teaching of science should be of especial interest to the readers of this journal, but this is never noteworthy at the meetings of the association, there being very few men of science in attendance. It is unfortunate that this is the case,

as it is of the utmost importance for scientific leaders to familiarize themselves with the teaching of science in the public schools. We ought to know, for example, why the number of high school students studying physics decreased during the past ten years from twenty-four to eighteen per cent. while the number studying Latin increased from forty to fifty per cent.

THE PROBLEM OF THE COLLEGE.

THE most interesting discussion at the meeting of the National Educational Association was one on the length of the baccalaureate course and the preparation for the professional schools, in which Presidents Eliot, Harper and Butler and Deans West and Hering were the official speakers. It is a most important question. There are now somewhat over 100,000 students in our colleges, universities and technical schools, and somewhat over 50,000 students in our professional schools of theology, law and medicine. In 1901, the last year for which the records have been published by the Bureau of Education, there were graduated from the colleges and technical schools 16,513 students, of whom 11,463 were men and 5,050 were women. Fifty different kinds of degrees were given to these graduates; but the classification of the commissioner of education is apparently faulty in attributing students of engineering to the colleges rather than to the professional schools. The number of regular academic bachelor degrees conferred was as follows: A.B., 7,943; B.S., 3,023; Ph.B., 1,112; B.L., 716. Of higher degrees the numbers were A.M., 1,280; M.S., 192; Ph.M., 22; M.L., 12; Ph.D., 343; Sc.D., 5. From the professional schools there were: graduates in theology, 1,585; in law, 3,366; in medicine, 5,472; in dentistry, 2,311; in pharmacy, 1,373; in veterinary medicine, 109. The number of students in theology has remained practically stationary since 1890; medical students have increased 73 per cent., and students of law to the remarkable extent of 202 per cent. In this period the men attending the colleges have increased 68 per cent. and the women 159 per cent., a relation which some will find gratifying and others will regard as ominous. The large figures do not represent the real increase in students, as the high school is now doing in large measure what was formerly done by the college. The increase in the number of high



NUMBER OF STUDENTS IN PUBLIC AND PRIVATE SECONDARY SCHOOLS.

school students, as shown in the accompanying chart, is truly remarkable. Worthy of note is also the fact that the increase is entirely a matter of the public secondary schools.

Of the 650,000 students in high, normal and preparatory schools, the 100,000 in colleges and the 50,000 in professional schools, the college students appear to cause the most difficulty to educators. The relation of the college to the high school on the

one hand, and to the professional school, on the other, is a problem that may ultimately be solved by the elimination of the old-fashioned college. The better high schools overlap the first two years of the weaker colleges, and the last two years of the college are often given in part to specialized or professional studies. Only one medical student in twelve holds a bachelor's degree. Our college is regarded as a distinctly American institution and is venerated as such. When there were but few high schools and when professional schools were private ventures, the college was the chief factor in education and culture. It is, however, now struggling for its existence, and has become so hybridized and diversified that there is no typical college.

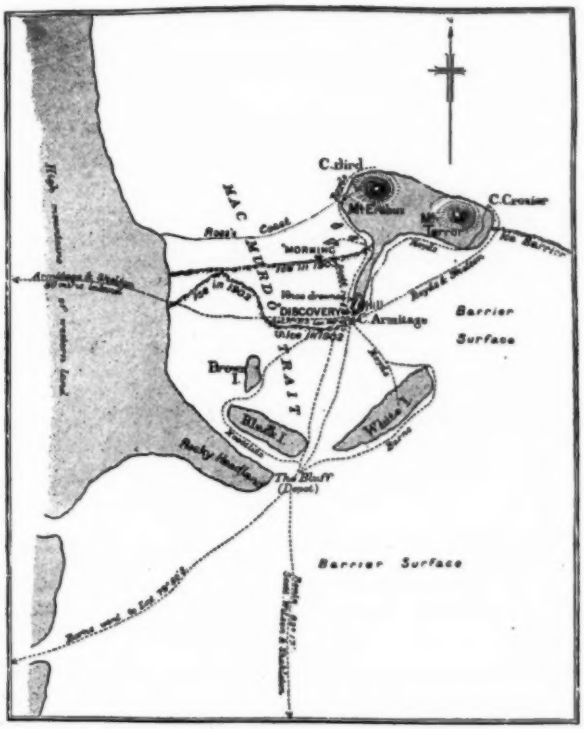
The differences of opinion among the college administrators who took part in the discussion at Boston were extreme. President Eliot has consistently urged a three-year college course, beginning at the age of eighteen, consisting of elective studies and required for the professional schools. Dean West said that three years might be quite long enough for electives, but that we should have a four-year course composed of 'disciplinary' studies. President Harper also favors four years, but allows a sliding scale. President Butler prefers a two-year course for students preparing for the professions, beginning at the age of sixteen or seventeen. All the college officers who spoke at Boston agree, however, that the college course must be prerequisite to the professional schools, at least to the better ones. None of them seemed to regard it as possible that the distinction between 'cultural' and useful studies is artificial. Certainly none of them suggested that the student should be set free to do his work, and the baccalaureate degree be given him on his twenty-first birthday.

THE BRITISH ANTARCTIC EXPEDITION.

ADVICES received in England and announced by the president of the Royal Geographical Society and others make it possible to form a reasonably correct estimate of the work accomplished by the British Antarctic Expedition and its present condition. The *Morning*, the relief ship under the command of Captain Colbeck, sighted the *Discovery* on January 23, but owing to the ice pack was not able to approach nearer to it than a distance of five miles. The *Morning*, having transferred the stores, left the ice on March 2, when there was already danger that she would become shut in. At this time it was hoped that the *Discovery* might be released from the ice, but this evidently proved impossible, as the ship would have reached New Zealand before this. We reproduce from the *Journal of the Royal Geographical Society* a sketch showing the position of the *Discovery*, the configuration of the land and the routes taken by the expeditions. It will be seen that the ice line was considerably further north in 1903 than in 1902, and unless it retreats in 1904, the *Discovery* must be abandoned. It is of course necessary under these circumstances to send a relief expedition again next year, and efforts are being made to collect money for this purpose. The government has been applied to for assistance, and the premier in the House of Commons recently, while implying that assistance would be granted, rather severely blamed the Royal Geographical Society and the Royal Society for not foreseeing this need.

The most dramatic result of the expedition was reaching the point furthest south, at latitude 82° 17′, from which land could be seen as far south as 83° 30′, with mountain ranges and peaks as high as 14,000 feet. The trip was made by Captain Scott, accompanied by Lieutenant Shackleton

and Dr. Wilson, who traveled nearly one thousand miles, drawing their sleds, after it had been necessary to kill the dogs owing to lack of food. Lieutenant Shackleton, who became ill, returned on the *Morning*, and is about to publish an account of the expedition. Another expedition headed by Lieutenants Armitage and Skelton went westward, climbing a glacier 9,000 feet high, the ice extending far inland. Other geographical results of interest were the discovery that Mts. Erebus and Terror are on a small island and that MacMurdo Bay is not a bay but a strait. The remaining scientific work of the expedition has not been reported on very fully. Magnetic work was carried on continuously, some 400 magnetograms having been taken; a seismograph was also working regularly; soundings and deep-sea dredgings were made, and undoubtedly valuable zoological and botanical collections were obtained.



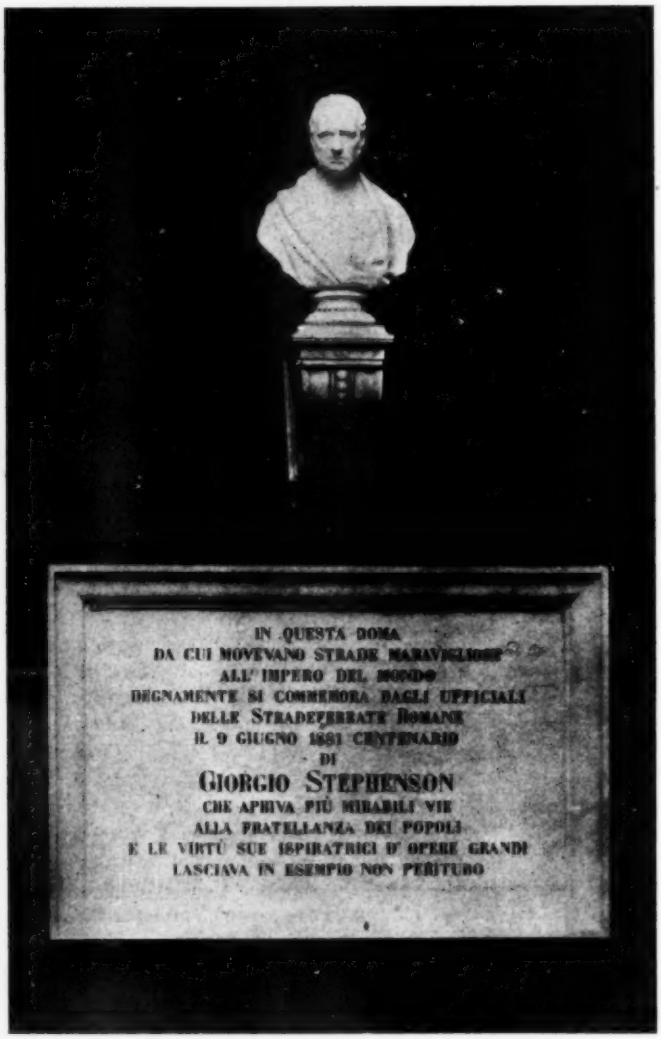
SKETCH SHOWING THE POSITION OF THE *Discovery* IN THE ANTARCTIC REGIONS.

THE SO-CALLED MOSQUITO DESTROYER.

THE New York *Sun* of July 13 printed an article to the effect that the Public Health and Marine-Hospital Service had discovered a parasite which would destroy mosquitoes, and from the account it appears as if the service intended to breed these worms in order to use them as a practical means for combating the mosquito plague. As the proposition is one which will doubtless attract popular attention, it will be well to place the exact facts before our readers.

A comparison of the *Sun's* account with the publications of the service

shows that the newspaper account is based directly upon an article by Dr. Stiles which is entitled 'A Parasitic Roundworm (*Agamomermis culicis*) in American Mosquitoes (*Culex sollicitans*),' and which appeared in 'Bulletin 13,' Hygienic Laboratory, of the service. In this article Dr. Stiles refers to several parasitic organisms which have been described from mosquitoes in different parts of the world and adds a new one to the list. This is a roundworm about half an inch long which lives in the abdominal cavity. He says: "At a time when mosquitoes are subjected to such careful study, because of the important relations they bear to public health, especially in connection with malaria, yellow fever, etc., it is of interest to determine what parasites


IN QUESTA DOMA
DA CUI MOVEVANO STRADE MARAVIGLIOSE
ALL' IMPERO DEL MONDO
DEGNAMENTE SI COMMEMORA DAGLI UFFICIALI
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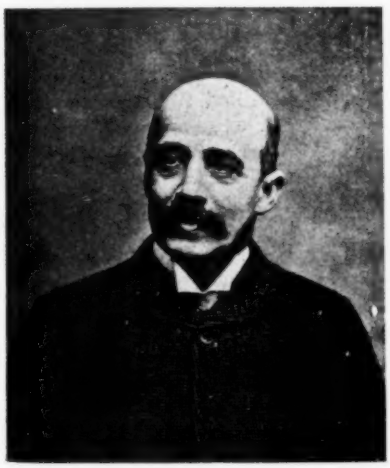
IL 9 GIUGNO 1881 CENTENARIO
DI
GIORGIO STEPHENSON
CHE APRIVA PIÙ MIRABILI VIE
ALLA FRATELLANZA DEI POPOLI
E LE VIRTÙ SUE ISPIRATRICI D' OPERE GRANDI
LASCIAVA IN ESEMPIO NON PERITURO

MEMORIAL TO GEORGE STEVENSON, RECENTLY ERECTED IN THE RAILWAY STATION AT ROME

naturally infest them. This determination has its practical as well as its scientific value, for it enables us to eliminate certain non-pathogenic parasitic organisms from the life cycle of pathogenic organisms, stages of which may be found in mosquitoes. It further has its direct practical bearing in that the parasites of mosquitoes may multiply to such an extent as to become important factors in killing the insects, or at least in rendering them less fertile."

He also refers to a similar *Agamomermis*, which he found in mosquitoes in Leipzig and which, according to



PAUL BELLONI DU CHAILLU, THE AFRICAN EXPLORER, WHO DIED ON APRIL 29, 1903.

Leuckart, seems to have an influence in decreasing the numbers of mosquitoes. Finally Dr. Stiles says: "These cases represent interesting instances in nature, where a pest is subject to other pests which tend to hold the former in check."

We do not find in the article any suggestion that the Public Health Service is breeding these worms for practical purposes, as intimated by the *Sun*, in order to kill mosquitoes. In fact, it would take considerable study to determine whether such a plan would be practicable. If this parasite could be bred artificially in sufficient numbers it is by no means an impracticable proposition to utilize them to destroy mosquitoes in regions where the use of kerosene is difficult or impossible. We do not, however, gather from the article the impression that the service proposes any such plan at present. In fact, we can see technical difficulties in the way which would make the method rather expensive, and it would, at most, be applicable only under certain conditions. We can not, therefore, hold out any great hope that *Agamomermis culicis*, which the New York *Sun* has named the 'mosquito destroyer,' presents to us at present a substitute for kerosene and proper drainage. But we share the view expressed in the original article that this represents 'a case of parasitism of considerable interest' and that parasites of mosquitoes, like parasites of other animals, 'may multiply to such an extent as to become important factors in killing the insects, or at least in rendering them less fertile.'

RADIUM IN ENGLAND.

THAT marvelous substance radium, some account of which was published in the POPULAR SCIENCE MONTHLY for July, 1900, and June, 1903, still attracts the attention of both men of science and laymen throughout intellectual nations. In London recently the luminescent property of the rays issuing from the element was shown to King Edward and Queen Alexandra, on the occasion of their visit to the London Hospital, and the penetrating power of the rays was also demonstrated by the following: A pile of six pennies was placed over a small piece of radium and the light emitted was visible through the coins.

At the Museum of Natural History, London, the director has arranged a little exhibition with a view to giving the public an opportunity of seeing the material and some of its interesting properties. Its source is shown in

specimens of uraninite, or pitchblende, one from mines in Cornwall, and the other from Bohemia; as is well known to readers of the MONTHLY, only a few decigrams of radium can be separated from a ton of the mineral, and the isolation of the element is difficult, owing to its chemical affinities with the metals of the alkaline earths (barium, strontium and calcium). In contrast with the velvety black, massive pitchblende, are a few decigrams of pure radium bromide, a white salt resembling exteriorly common salt. Near by is a salt of barium, the crystals of which are rendered luminous when exposed to the emanations from a radium compound, even when a pile of copper coins, or a piece of marble more than one inch in thickness, is placed between them. The labels on these specimens duly explain that these emanations also act in the dark on photographic plates, and make the air traversed by them conductive of electricity.

The exhibition also includes the following: A box blackened inside and mounted on a stand, the whole resembling somewhat a large photographic camera, especially since the open end of the box is screened with black velvet that might be mistaken for a focusing cloth. On raising this screen the visitor sees at the farther end in letters of light, the word R-A-D-I-U-M. This word has been painted with radium bromide on hexagonal sulphide of zinc, which becomes luminous when brought near a compound of radium. Thus the emission of light by the new element is demonstrated as effectively, though not so strikingly as by Sir William Crookes in his experiments at the conversazione of the Royal Society, when the scintillations of radium were rendered visible by means of a blende screen and intensified by the use of a lens of moderate magnifying power. Residents of London, and visitors to that metropolis, will enjoy forming practical acquaintance with radium and with some of its extraordinary properties that may be envied by citizens of America.

THE FRANKLIN PAPERS IN THE LIBRARY OF THE AMERICAN PHILOSOPHICAL SOCIETY.

AT the meeting of the American Philosophical Society last spring, Mr. J. G. Rosengarten gave an account of some seventy large folio volumes of Franklin's papers, preserved in the archives of the society. Franklin left all his papers to his grandson, William Temple Franklin, who, after a long interval, published in London and in Philadelphia six volumes of Franklin's works. Of course, this represented but a small part of his papers. Those used in the preparation of Temple Franklin's edition are now the property of the United States, which has never yet printed a calendar of them. Temple Franklin selected from his grandfather's papers those that he thought suitable for publication, and left the rest of them in charge of his friend, Charles Fox, to whom he bequeathed them, and Charles Fox, in turn, after a long lapse of years, presented them to the American Philosophical Society, in whose custody they have remained ever since.

They have been roughly classified, and are bound in a rude and careless way. Under the present efficient librarian, Dr. Hays, a calendar is being made as fast as the limited means at his disposal will permit, and, when it is completed, it is hoped that it will be printed as a useful guide to the miscellaneous matter collected here. Sparks, Hale, Ford, Parton, Fisher and others who have written about Franklin have used them, but even the most industrious student may well be appalled at the labor required to master all the contents of these bulky volumes representing Franklin's long and many-sided activity.

He kept copies of most of his own letters and the originals addressed to him, often indorsing on them the heads

of his replies. These volumes contain papers from 1735 to 1790—the first forty-four volumes, letters to him; the forty-fifth, copies of his own letters; the forty-sixth, his correspondence with his wife; the forty-seventh and forty-eighth, his own letters from 1720 to 1791; the forty-ninth, his scientific and political papers; the fiftieth, his other writings—notably his Bagatelles, those short essays which had such a vogue, and which are still read; the fifty-first, poetry and verse, his own and that of others, no doubt selected by him for use in his publications; the fifty-second, the Georgia papers—he was agent for that colony; and the remaining twenty volumes, all the multifarious correspondence, other than official, mostly during his long stay in France, his various public offices at home and abroad, his enormous correspondence about appointments from men of all nationalities, who wanted to come to America under his patronage to fight, to settle, to teach, to introduce their inventions for every imaginable and unimaginable purpose.

Both in England and France he kept all notices of meetings, such as those of the Royal Society, and other scientific bodies of which he was a member, invitations, visiting cards, notes, business cards, etc., and at home he kept copies of wills, deeds, powers of attorney, bonds, agreements, bills and drafts, checks, bills of lading, public accounts and even certified copies of acts of congress and account books. It is to be hoped that the preparation and publication of the calendar showing the contents of this rich mass of materials may be completed at no distant day, certainly by the two hundredth anniversary of the birth of Franklin.

THE EDUCATION OF ENGINEERS.

At a recent meeting of the British Institution of Mechanical Engineers, Professor W. E. Dalby read a paper on 'The Education of Engineers in America, Germany and Switzerland.' According to the report in the London *Times*, the author pointed out that with scientific progress, changing methods of manufacture and the advent of electricity, there has been scarcely any change in the recognized methods of training engineers. At the present time, however, there is no difficulty in obtaining scientific instruction of a high character, and a training in workshop practise second to none can be secured in the factories of this country. The weak point is the want of cooperation between the workshops and the colleges. The author proceeded to give details of the course of instruction followed at the Massachusetts Institute of Technology, Boston, U. S. A.; at Sibley College, Cornell University; at the Berlin Technical High School, and at the Swiss Federal Polytechnic School at Zurich. There is an essential difference in the methods of training in America and Germany.

In America the course of instruction is very exactly laid down; in Germany no student is compelled to take any special course, though, for his convenience, definite courses are laid down in the school calendar. At Zurich the course is partly prescribed and partly selected. The American course may be taken as 3,000 hours, distributed over four years; the continental course is 4,000 hours, distributed over three years, independently of laboratory work. The fourth year is not included, as it is cut up by examination work. In America a large proportion of the time is devoted to workshop practise; in Germany and Switzerland no time at all is thus occupied. The American courses are more practical in character and devote a large proportion of the course to the teaching of handicraft skill. In America a student finds himself with a degree or diploma at the age of twenty-one. Employers take him without premium and

pay a wage sufficient for maintenance straightway, recognizing that his knowledge places him in a different position to ordinary apprentices. In this way they get highly-trained men into their works, and by their own observation soon discover whether the youth possesses, in addition to intellectual acuteness, the qualities which go to make a successful business man or a good organizer, and recruit their staff accordingly. The author suggested the question whether the British method of training was better or worse; whether the methods could be improved in the light of what was being done abroad. Most people, he said, would consider the methods of Charlottenburg and Zurich too academical; whilst many, though admiring the American system of workshop instruction, think it better it should be obtained under the practical conditions of actual work. A youth who is to become a leader in the future needs to know the habits and thoughts of the men. One thing the author considered certain—the American, German or Swiss student starts his college course with a far better education on which to build.

SCIENTIFIC ITEMS.

DR. CARL GEGENBAUER, the eminent anatomist, since 1863 professor at Heidelberg, died on June 15, at the age of seventy-seven years.—Dr. A. A. Common, F.R.S., known for his important researches in astronomy, especially in connection with reflecting telescopes, died on June 2, at the age of sixty-two years.

A COMMITTEE of eminent chemists has been formed to erect a monument at Heidelberg in memory of Robert Bunsen. It is intended that the contributions shall be international; they may be sent to the treasurer, Herr A. Rodrian, Heidelberg.

THE park commissioners of Chicago have approved the transfer of the Field Columbian Museum from Jackson Park to Grant Park, which is on the lake front in the center of the city. It is understood that Mr. Marshall Field has agreed to give $5,000,000 for the construction and endowment of the museum.—It is said that the trustees of the Rush Medical College, the medical department of the University of Chicago, have collected $1,000,000 for the institution, and that this assures a gift of $6,000,000 to the school by Mr. John D. Rockefeller.